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# United States Patent [19]

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Heidmann et al.

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[54] **CHAIR WITH RECLINEABLE BACK AND ADJUSTABLE ENERGY MECHANISM**

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[73] Assignee: **Steelcase Inc.**, Grand Rapids, Mich.

[\*] Notice: This patent is subject to a terminal disclaimer.

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[21] Appl. No.: **08/957,506**

[22] Filed: **Oct. 24, 1997**

[51] Int. Cl.<sup>7</sup> ..... **A47C 3/00**

[52] U.S. Cl. .... **297/300.1; 297/300.4;**  
**297/300.5; 297/303.4; 297/303.3**

[58] Field of Search ..... **297/303.1, 303.4,**  
**297/303.5, 300.1, 342, 341, 300.2, 300.4,**  
**300.5, 303.3**

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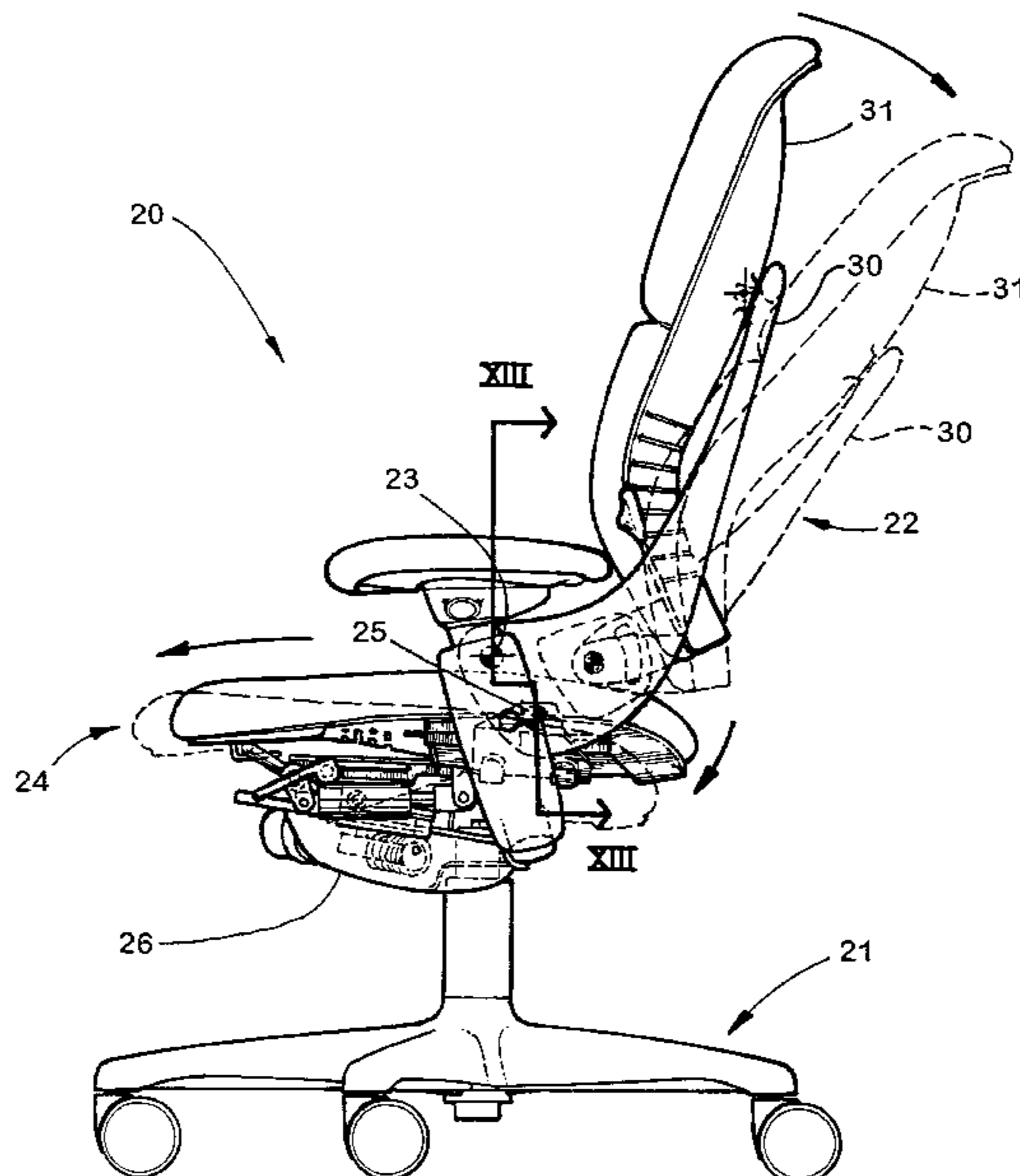
*Primary Examiner*—Milton Nelson, Jr.

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[57] **ABSTRACT**

A chair is provided having a base assembly including a base frame, a back frame pivoted to the base frame for movement between upright and reclined positions, and a seat slidably supported on the base frame and pivoted to the back frame so that the seat moves forwardly and its rear moves forwardly and downwardly with the back frame upon recline. A flexible back is connected to the back frame at top and bottom locations and is provided with lumbar adjustment for improved lumbar force/support and shape. A seat is provided with seat depth adjustment and with active and passive thigh flex support. A novel energy mechanism is provided that includes a transverse spring, a lever, and a moment arm shift adjuster for adjusting the spring tension on the back frame. The moment arm shift adjuster is readily adjustable and includes an overtorque device to prevent damage to components of the energy mechanism.

**37 Claims, 38 Drawing Sheets**



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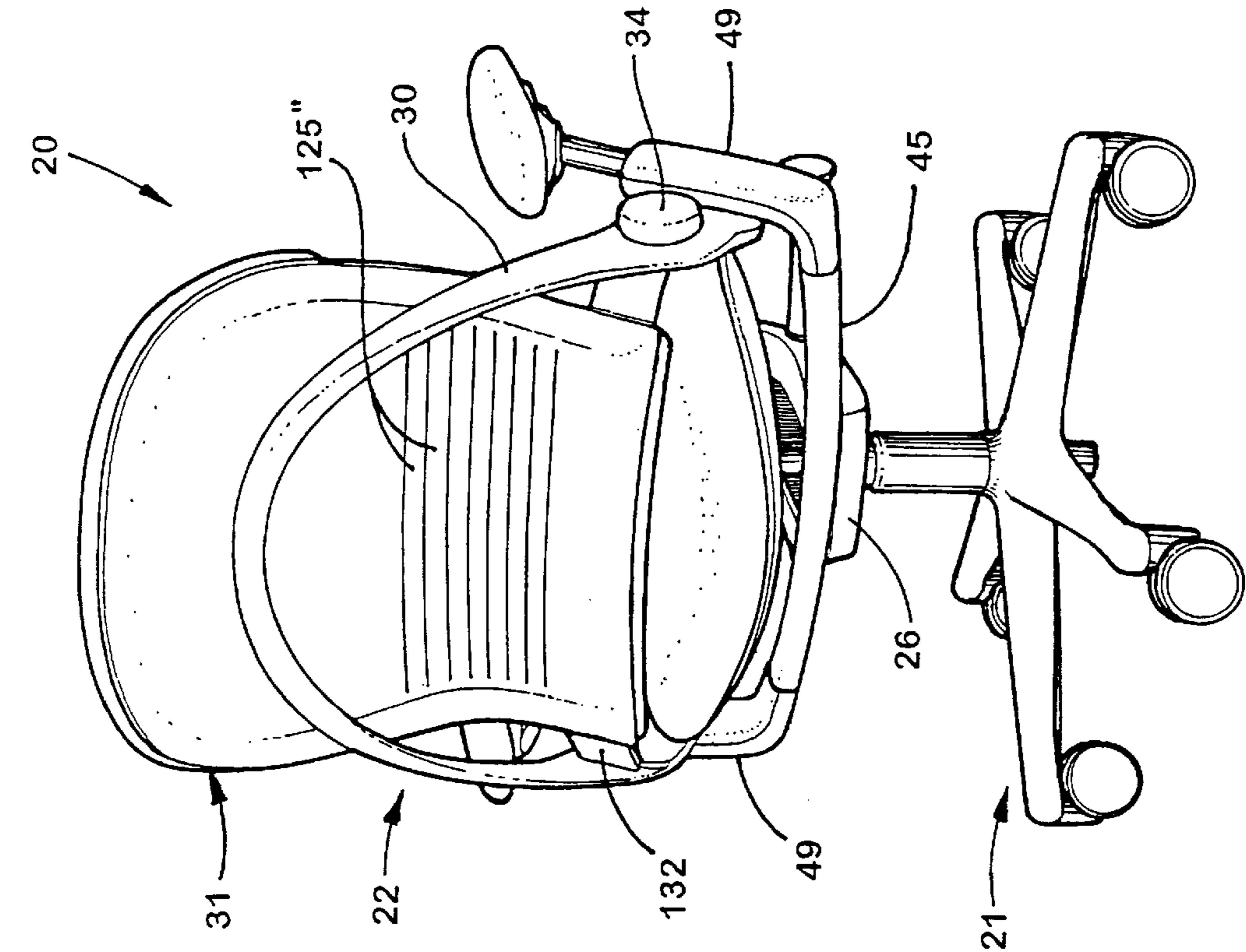


Fig. 1

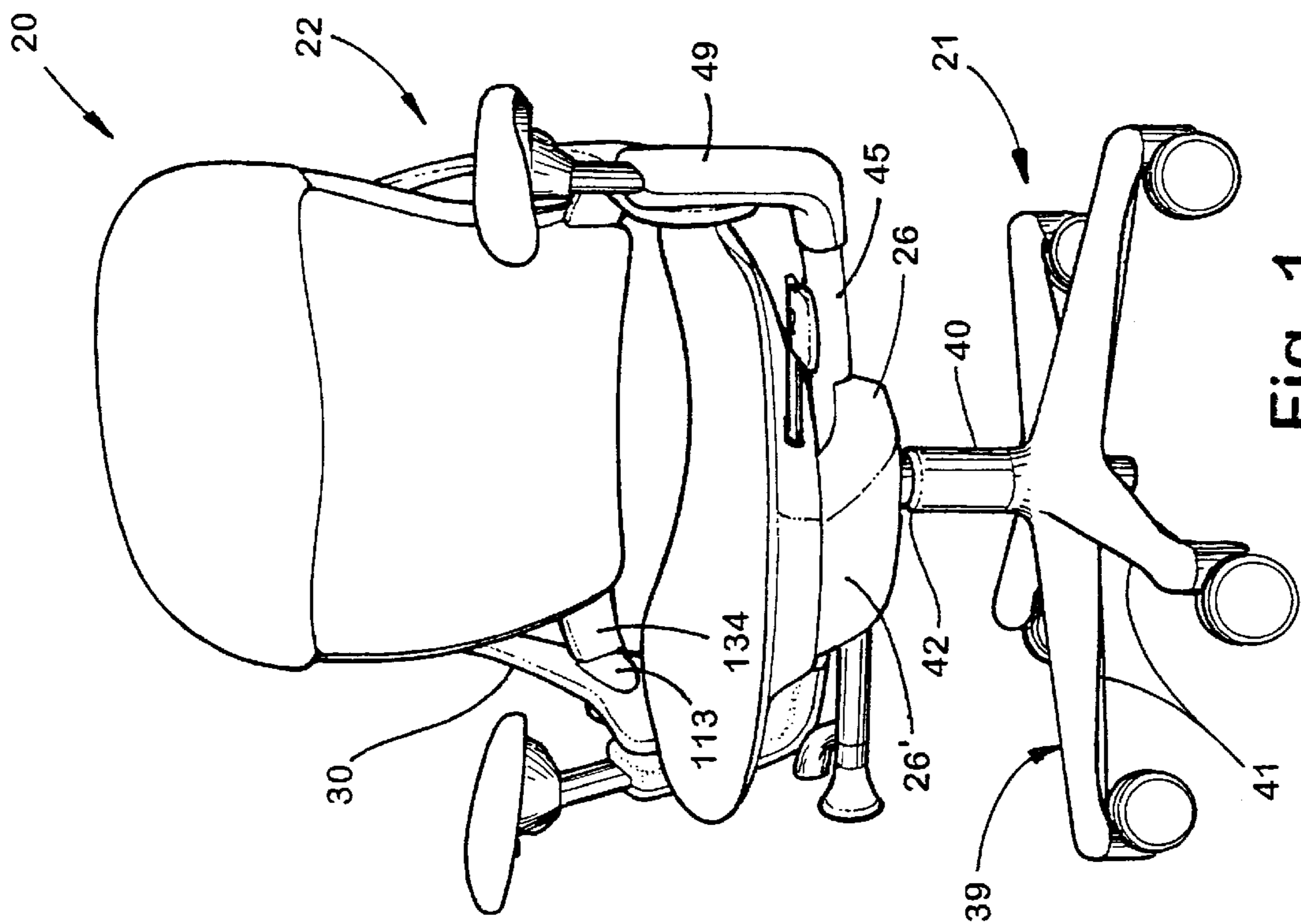


Fig. 2

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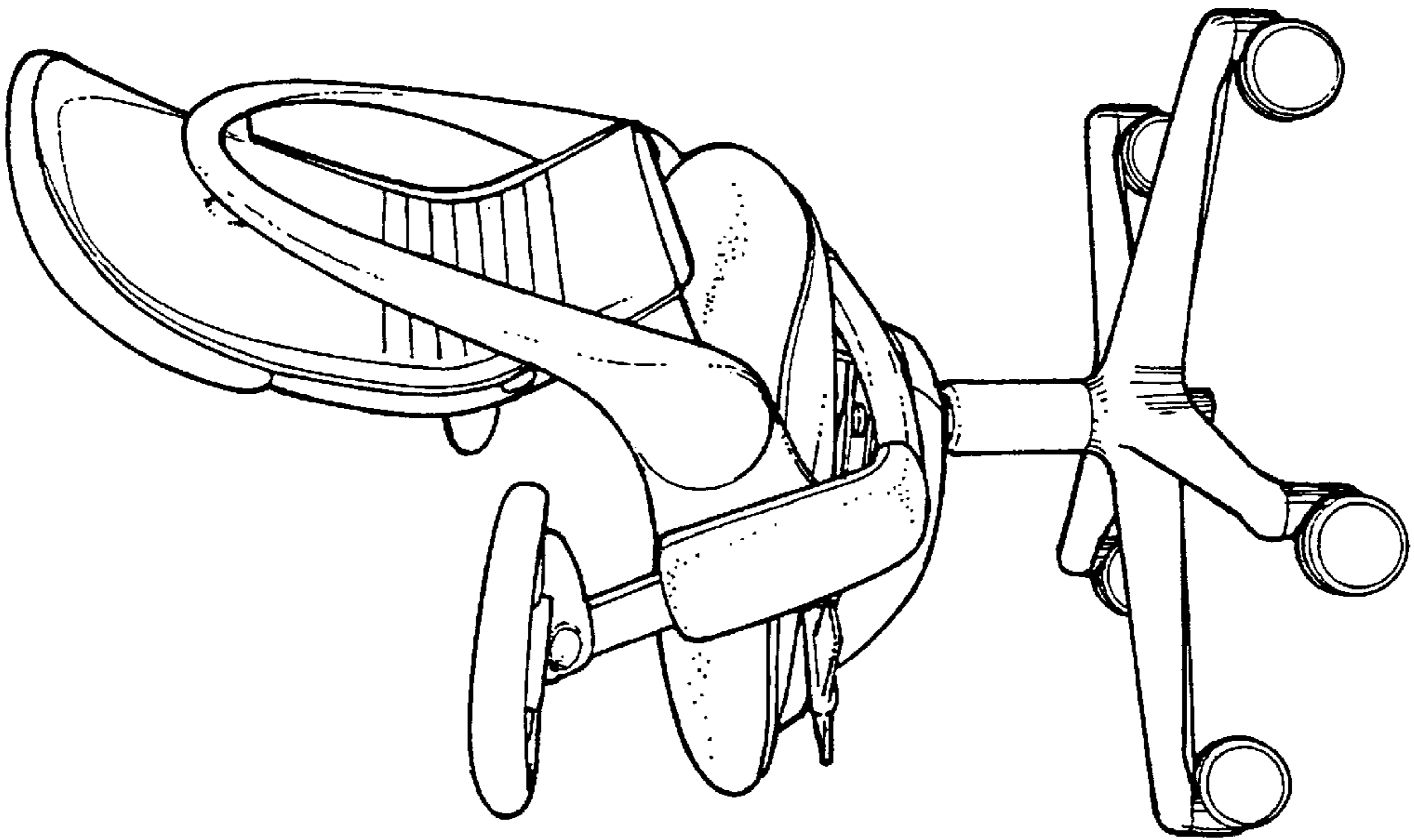


Fig. 3

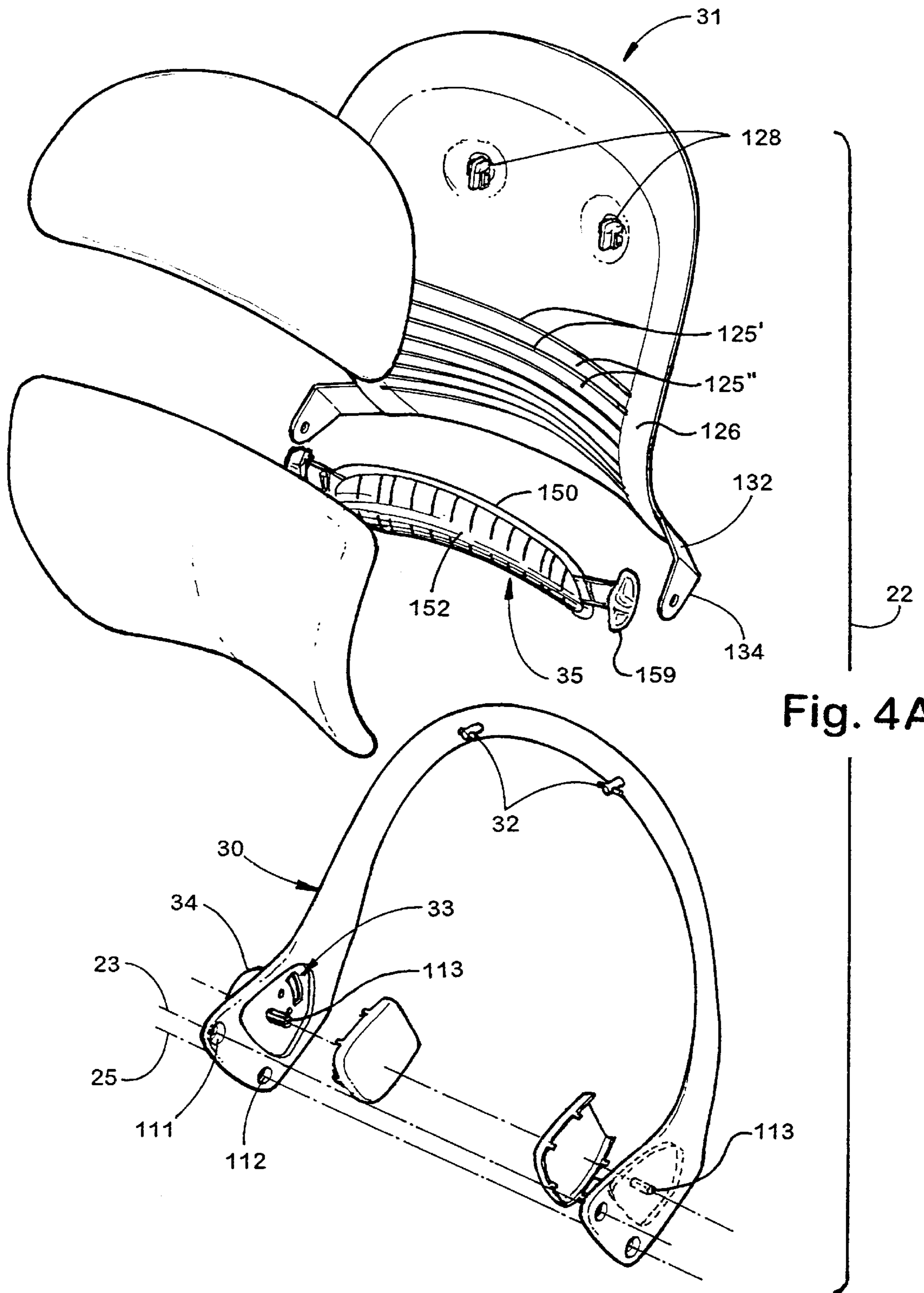


Fig. 4A

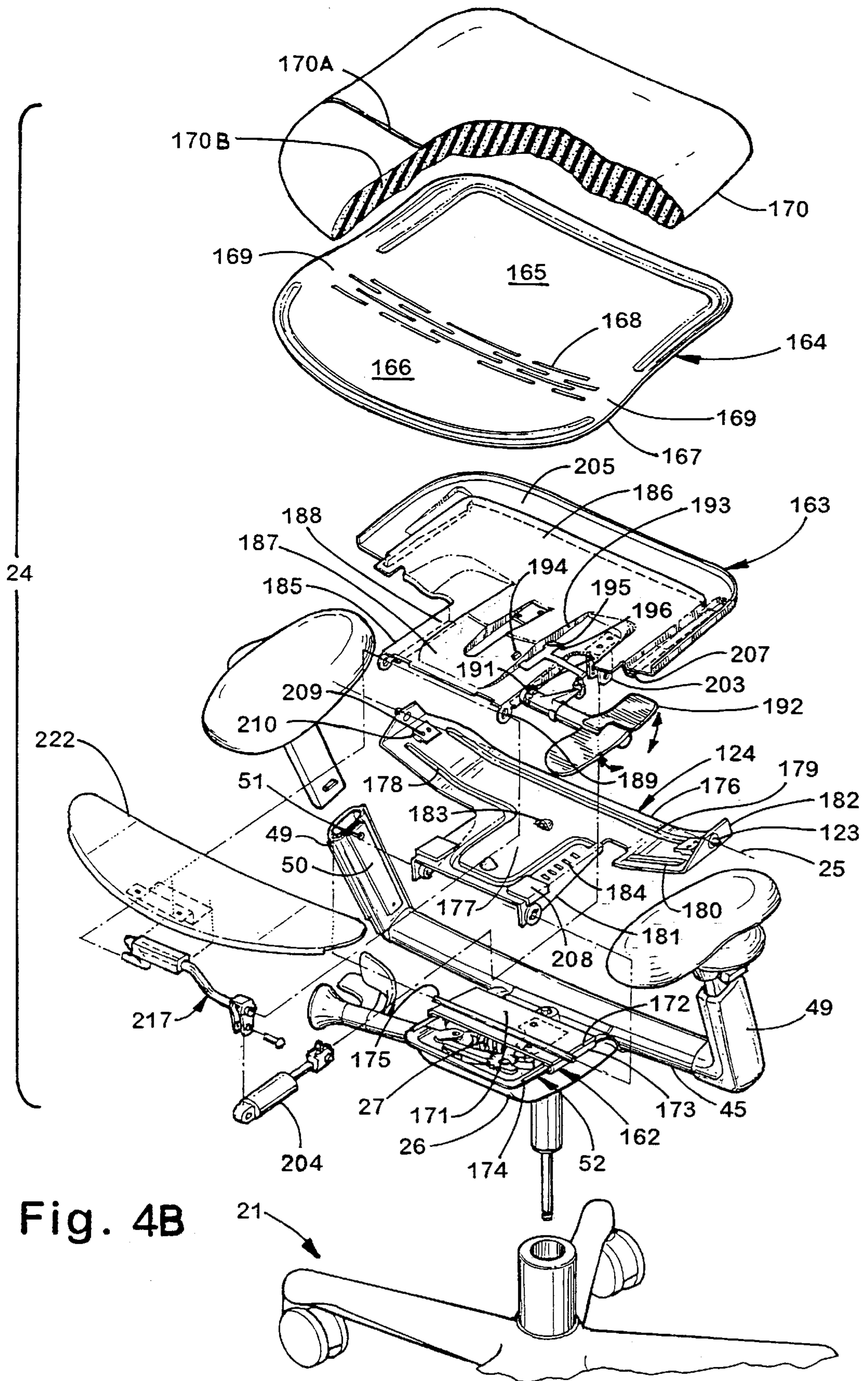


Fig. 4B

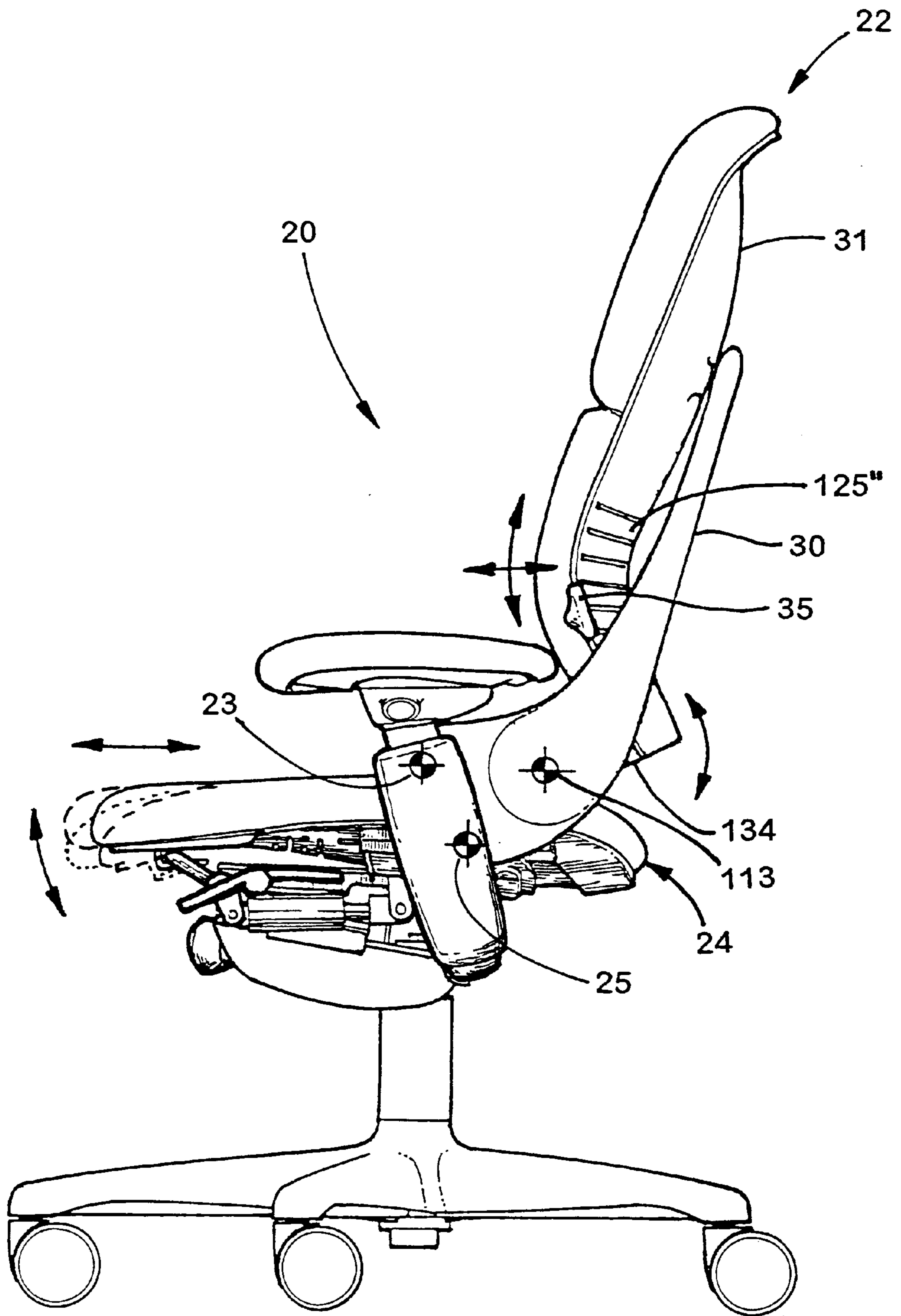


Fig. 5

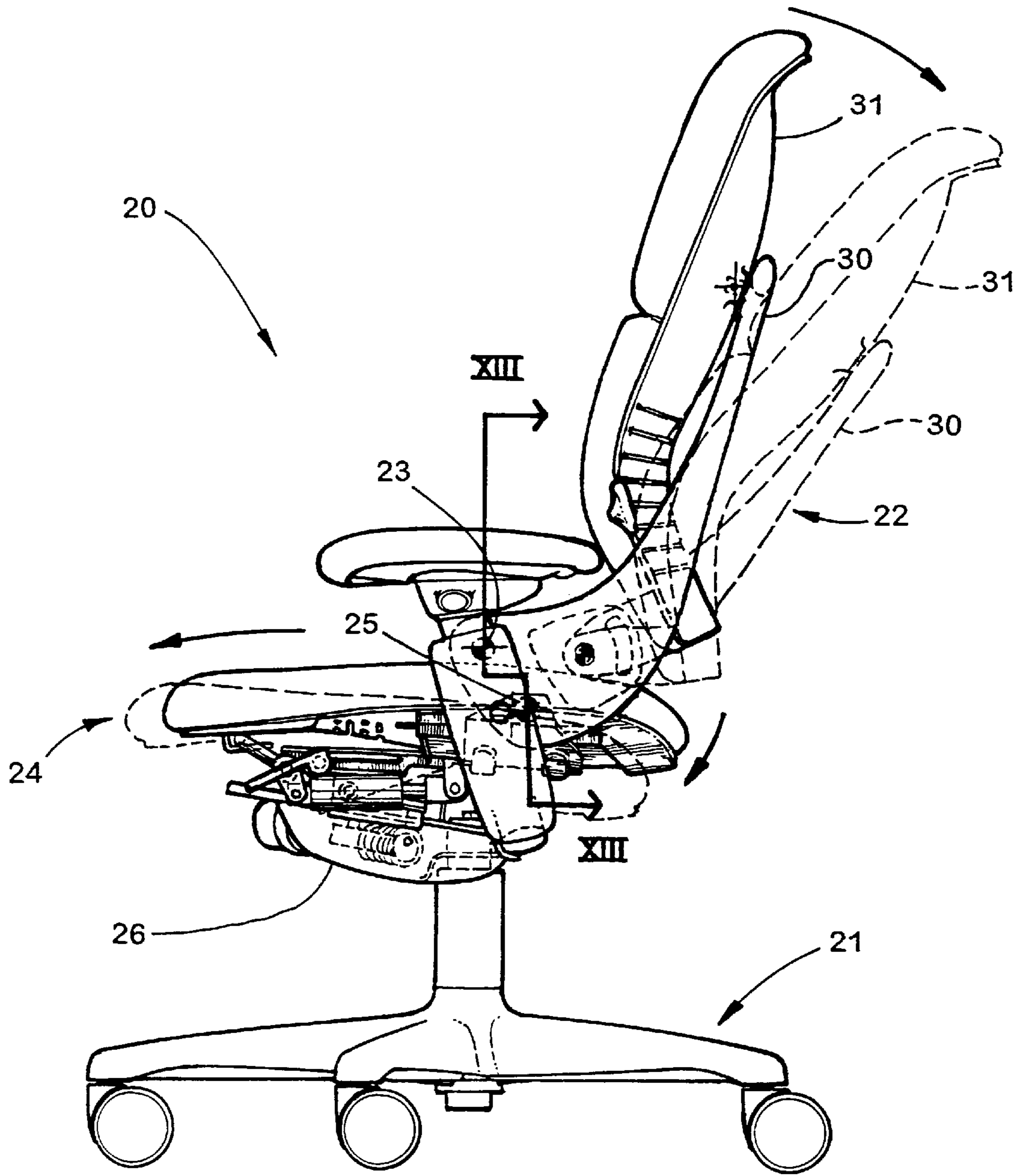


Fig. 6



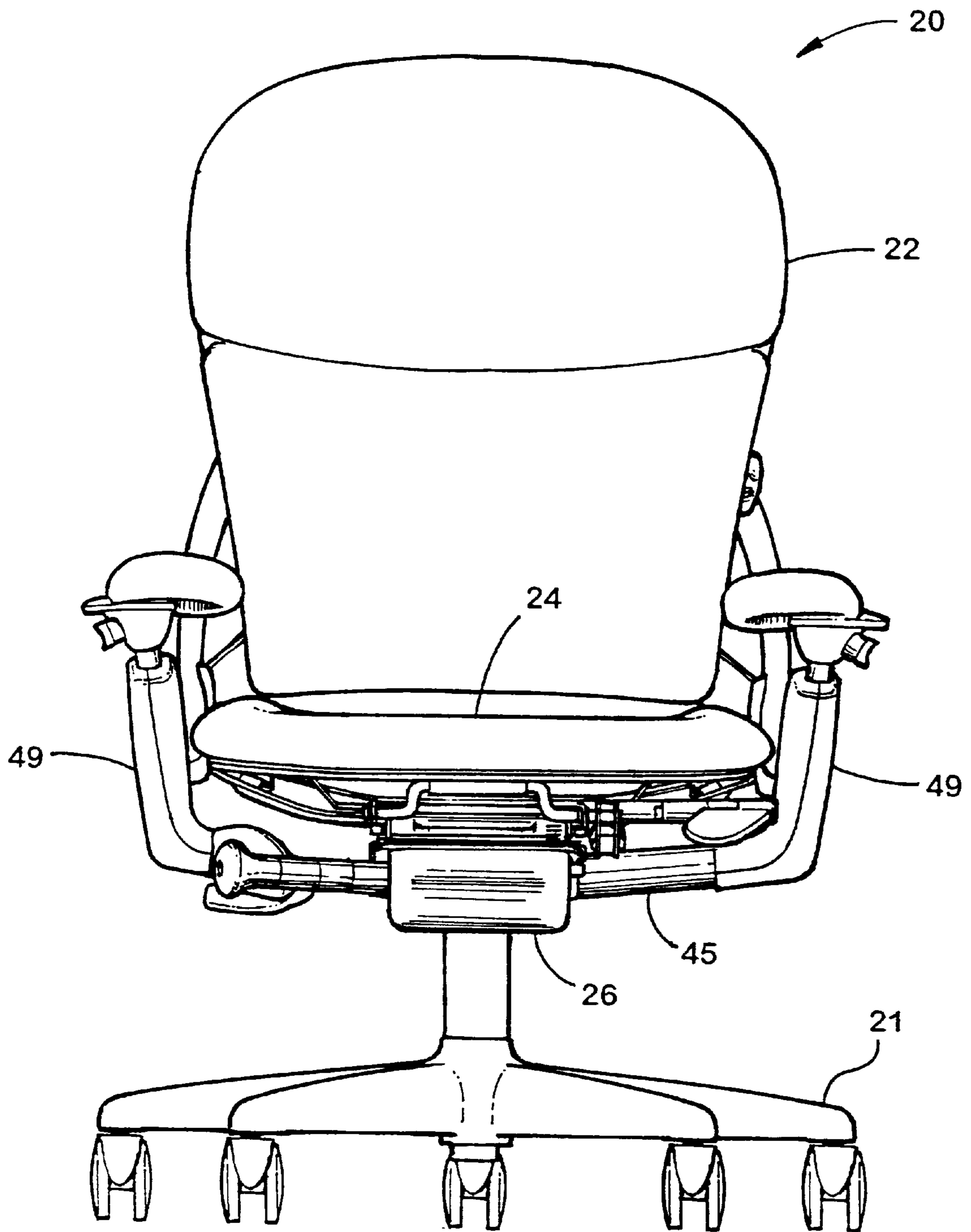


Fig. 7

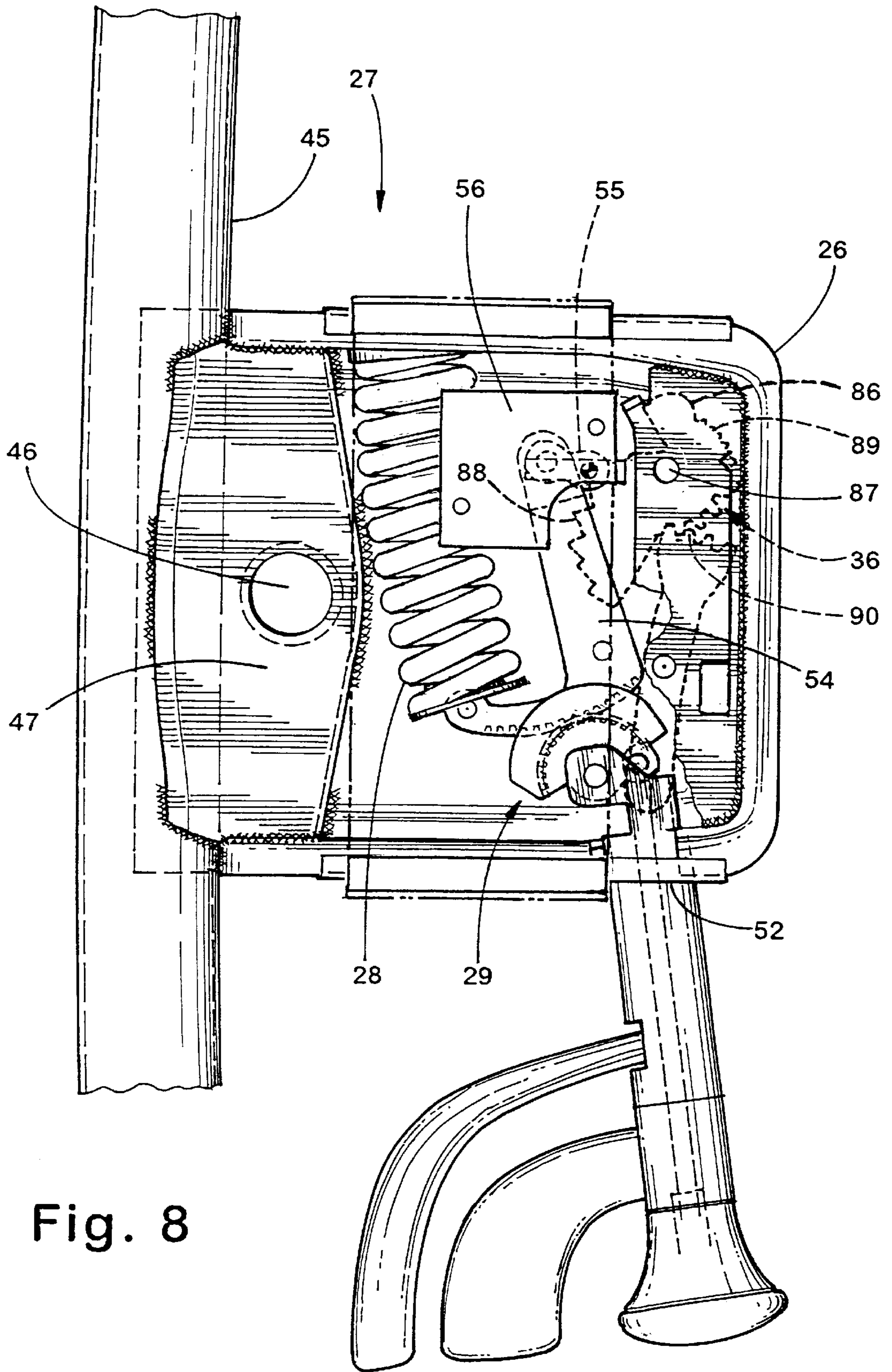


Fig. 8

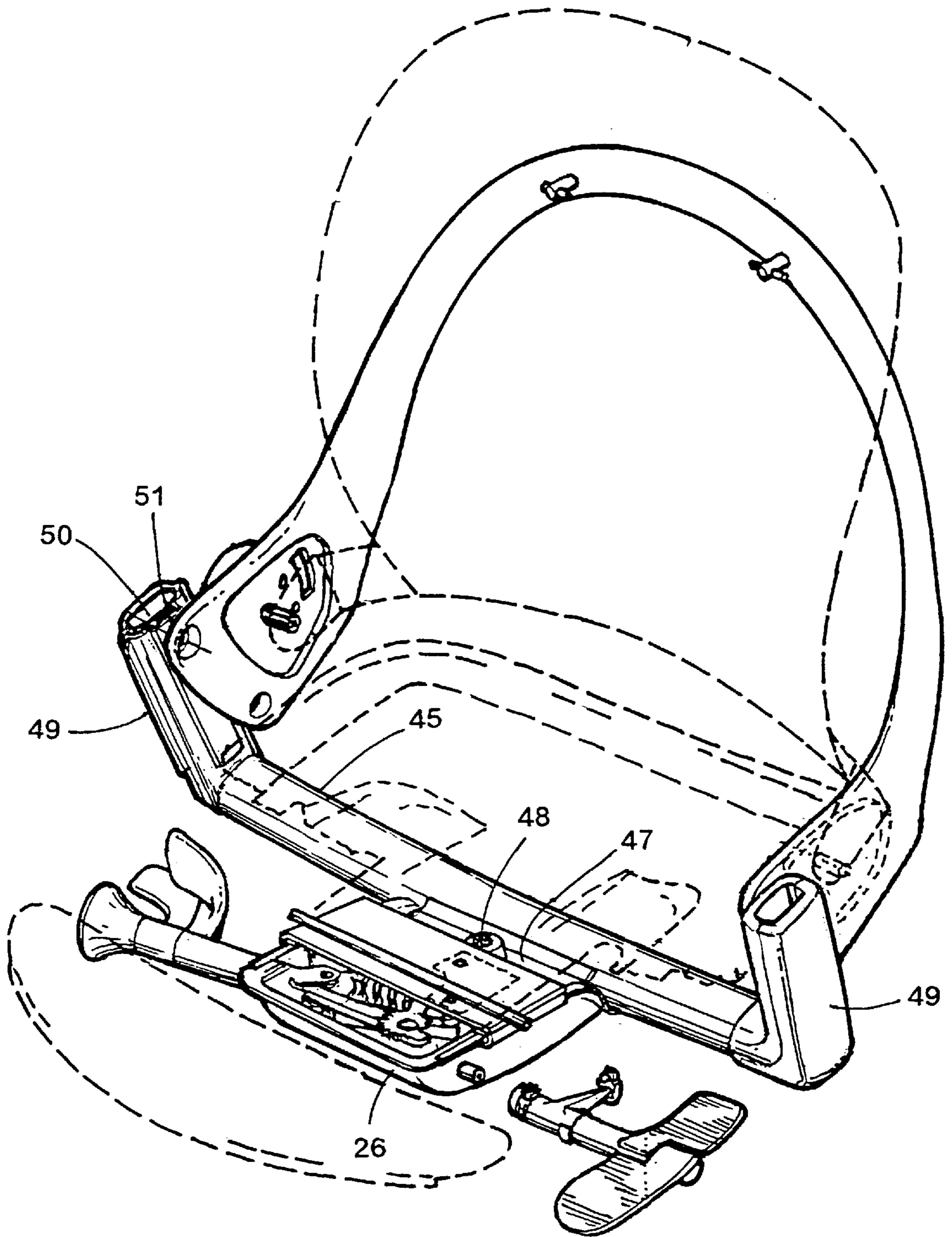


Fig. 8A

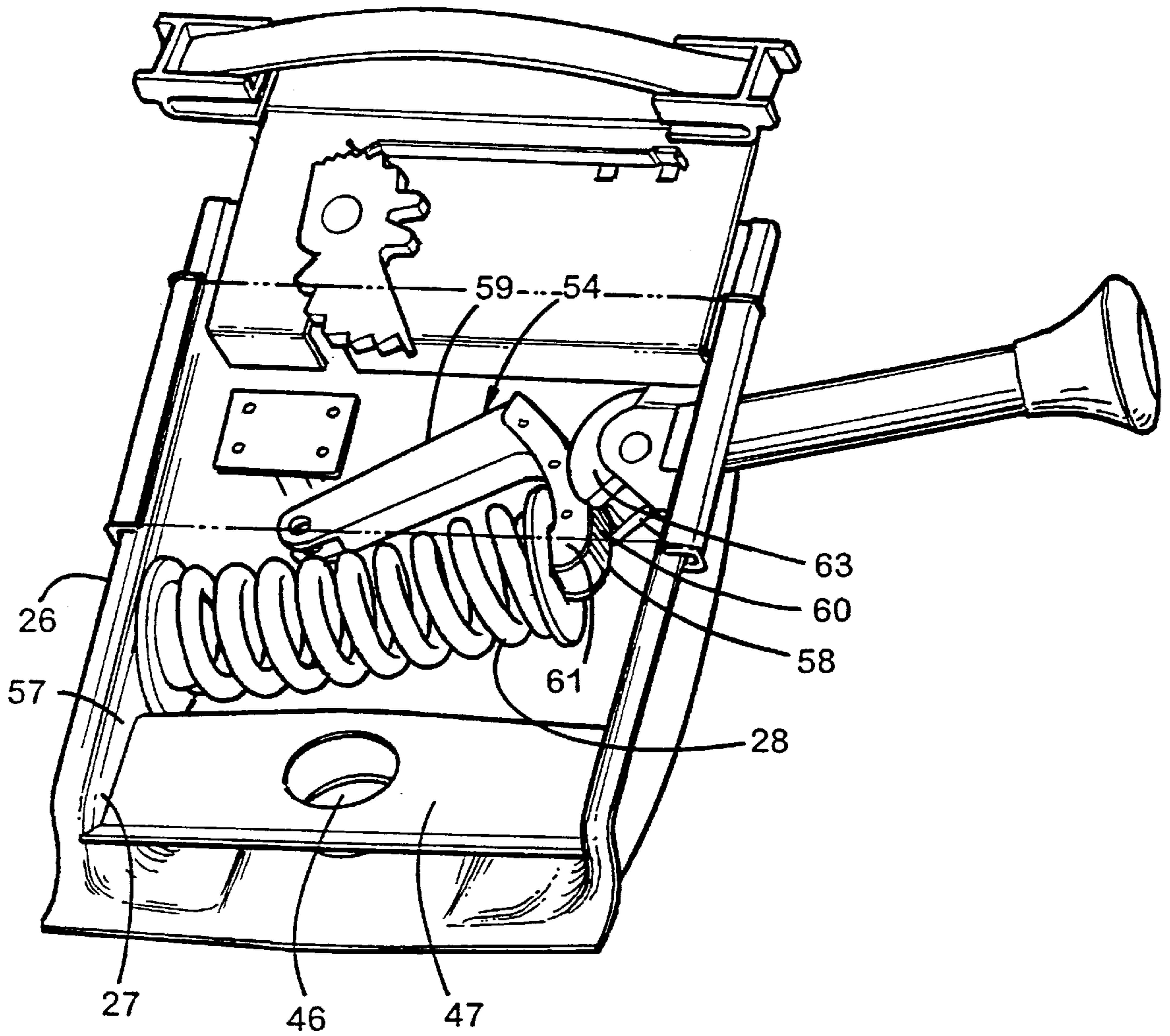


Fig. 9

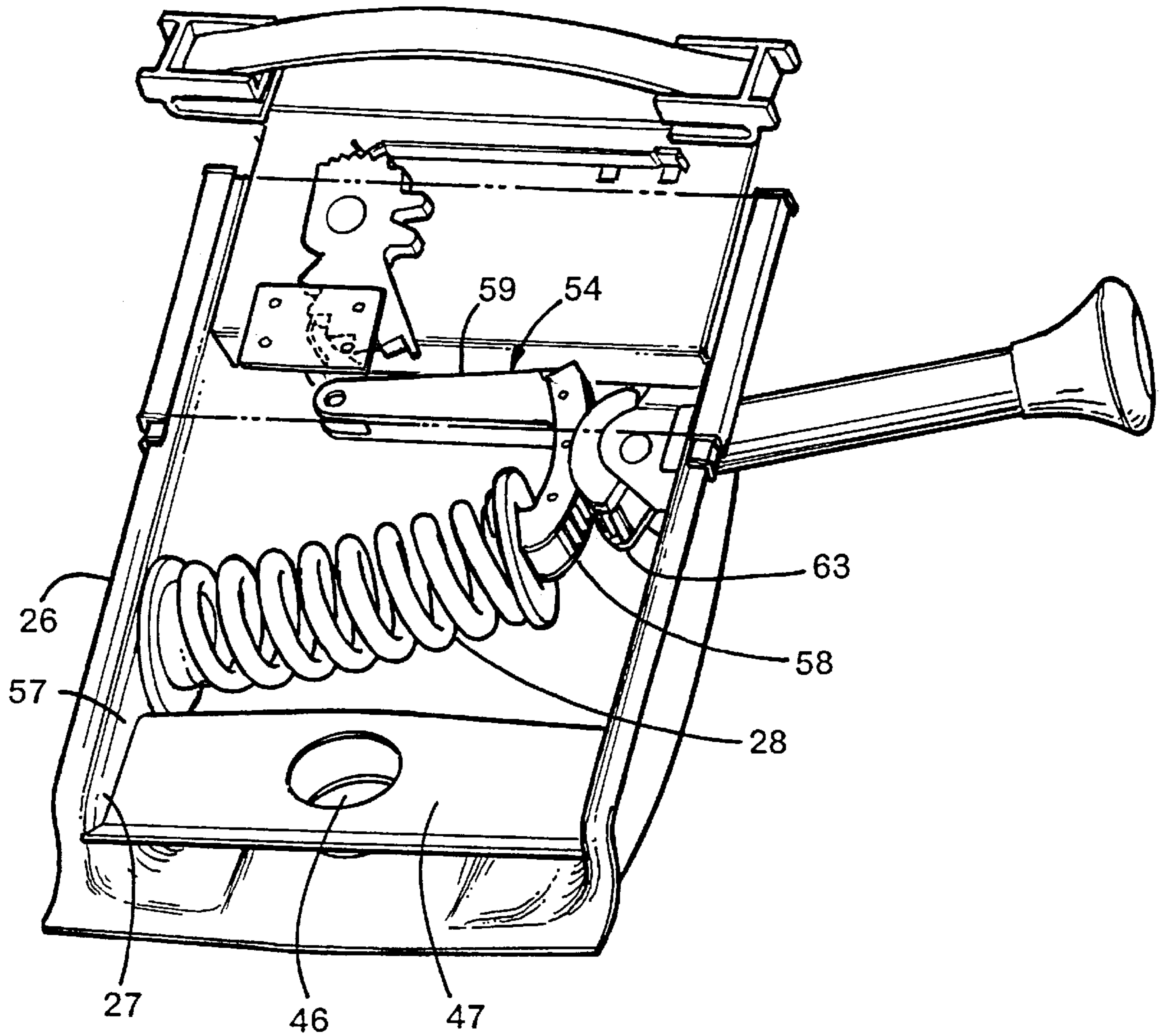


Fig. 9A

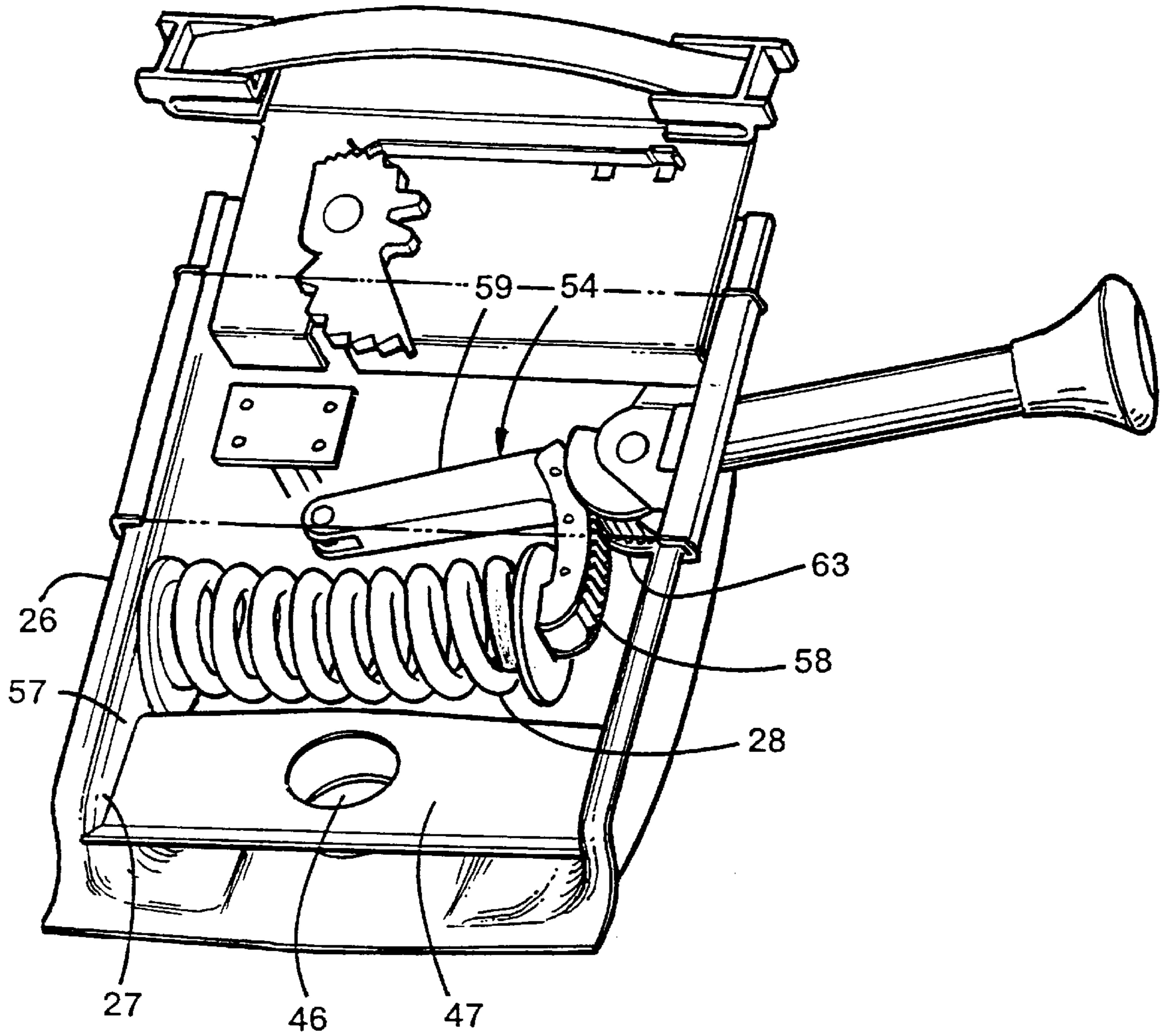


Fig. 9B

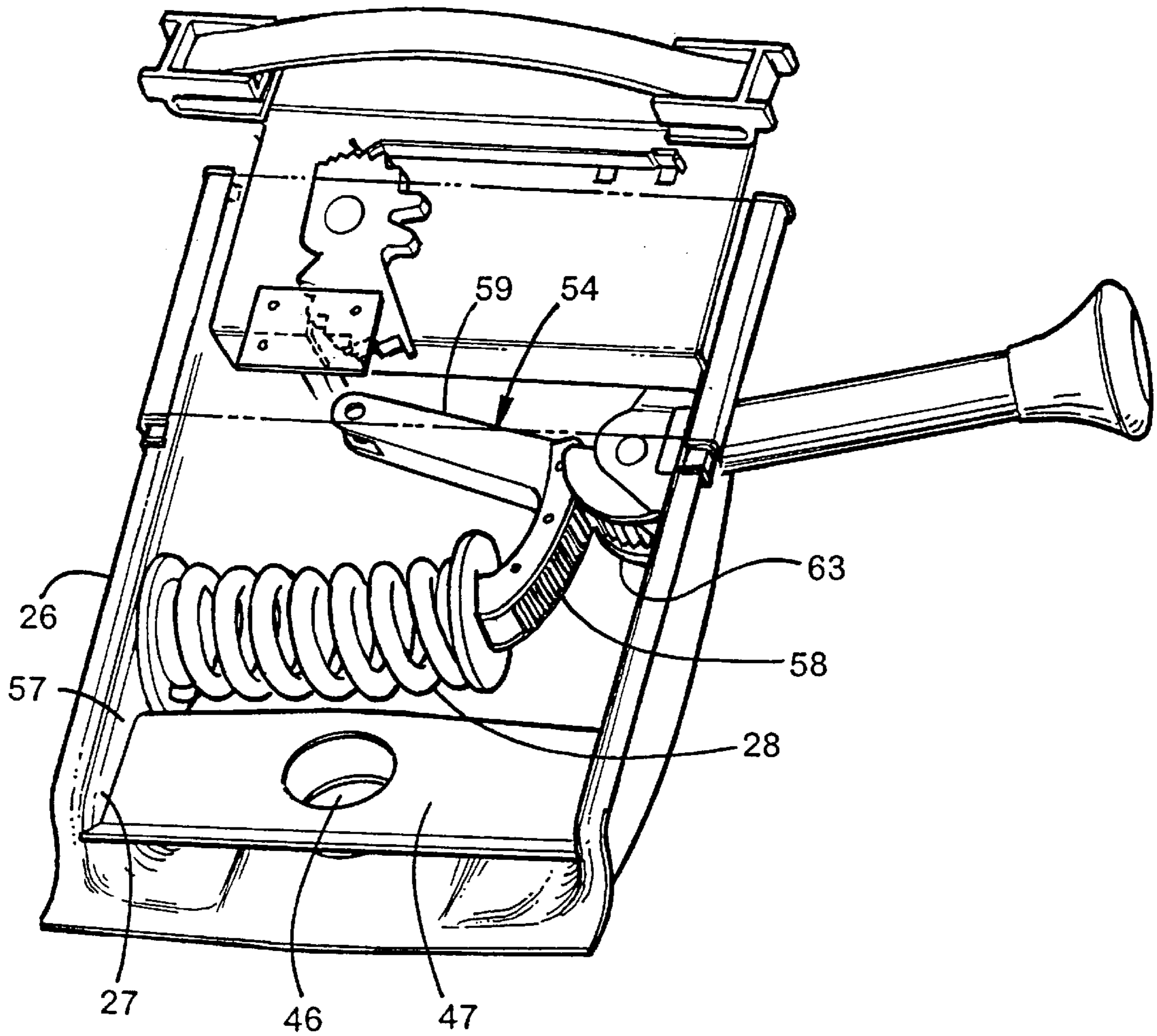


Fig. 9C

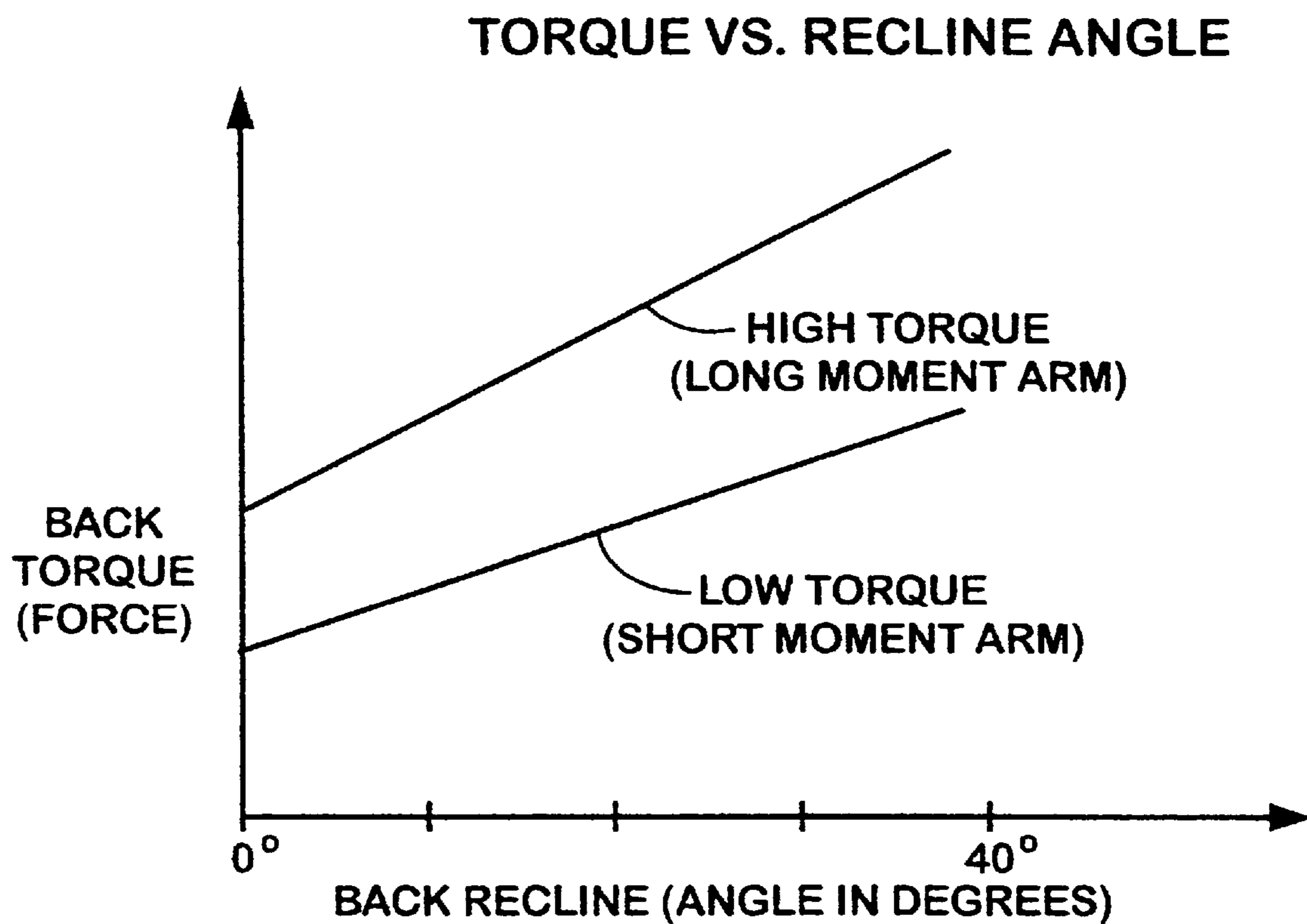


Fig. 9D



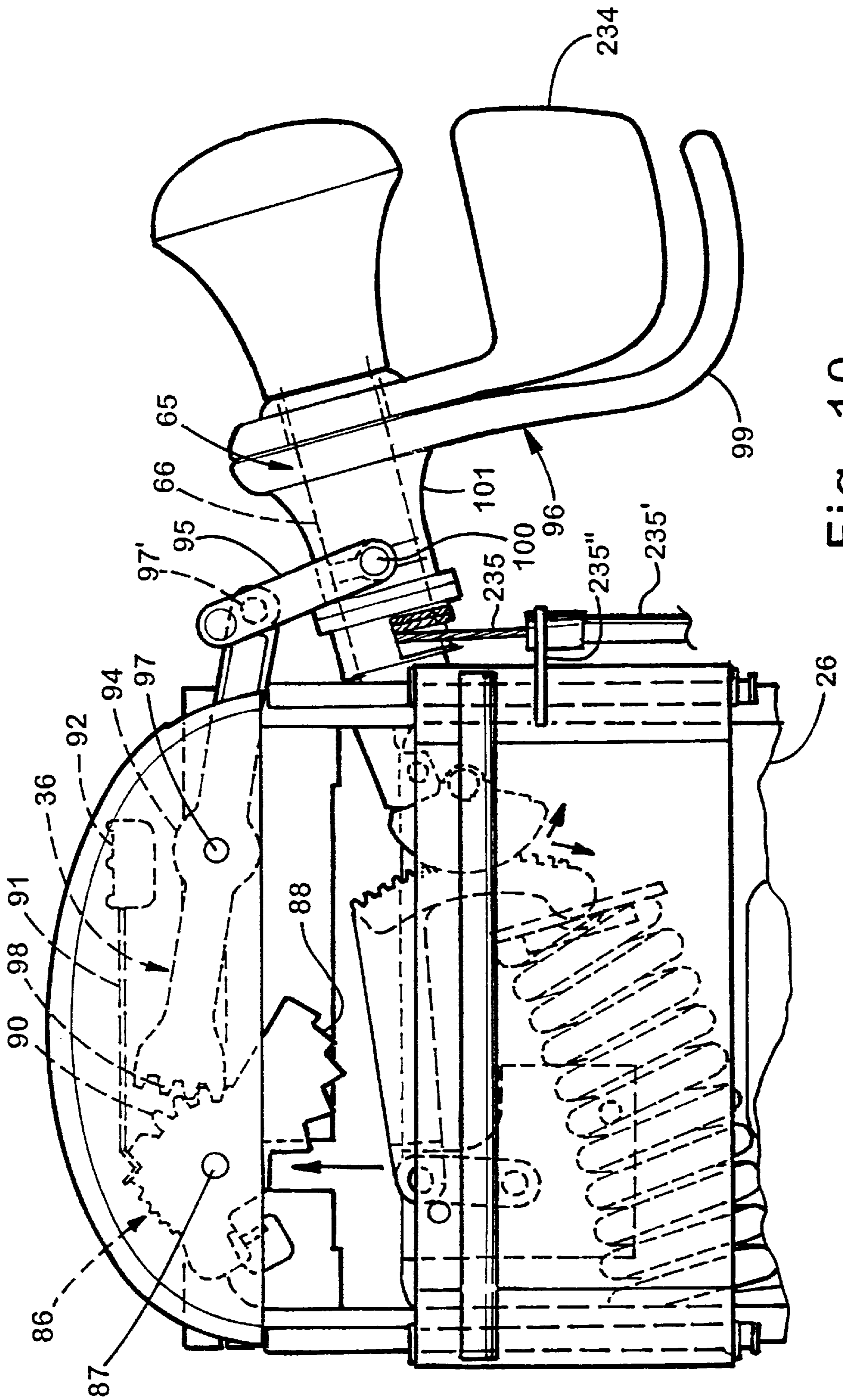


Fig. 10

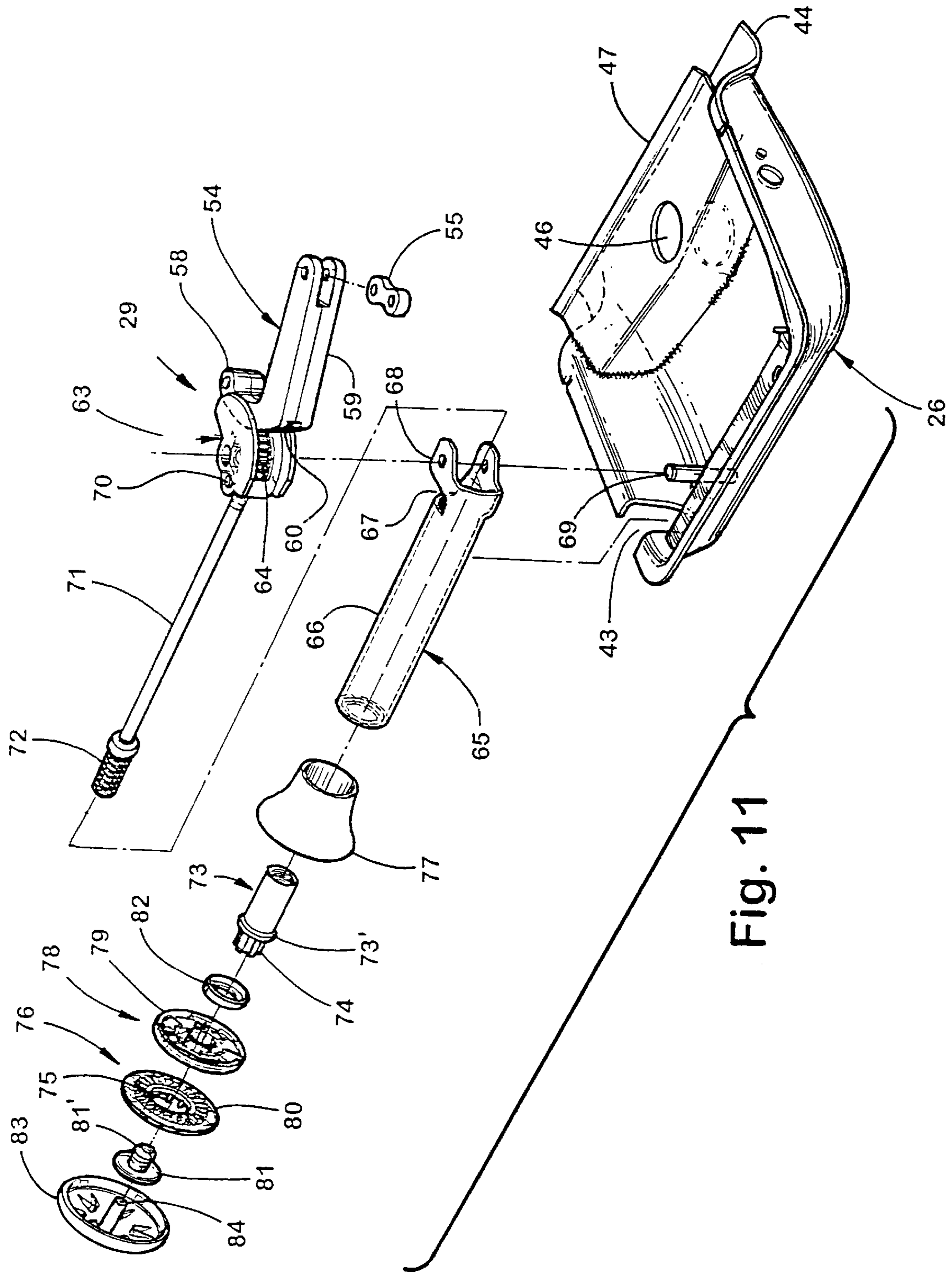


Fig. 11

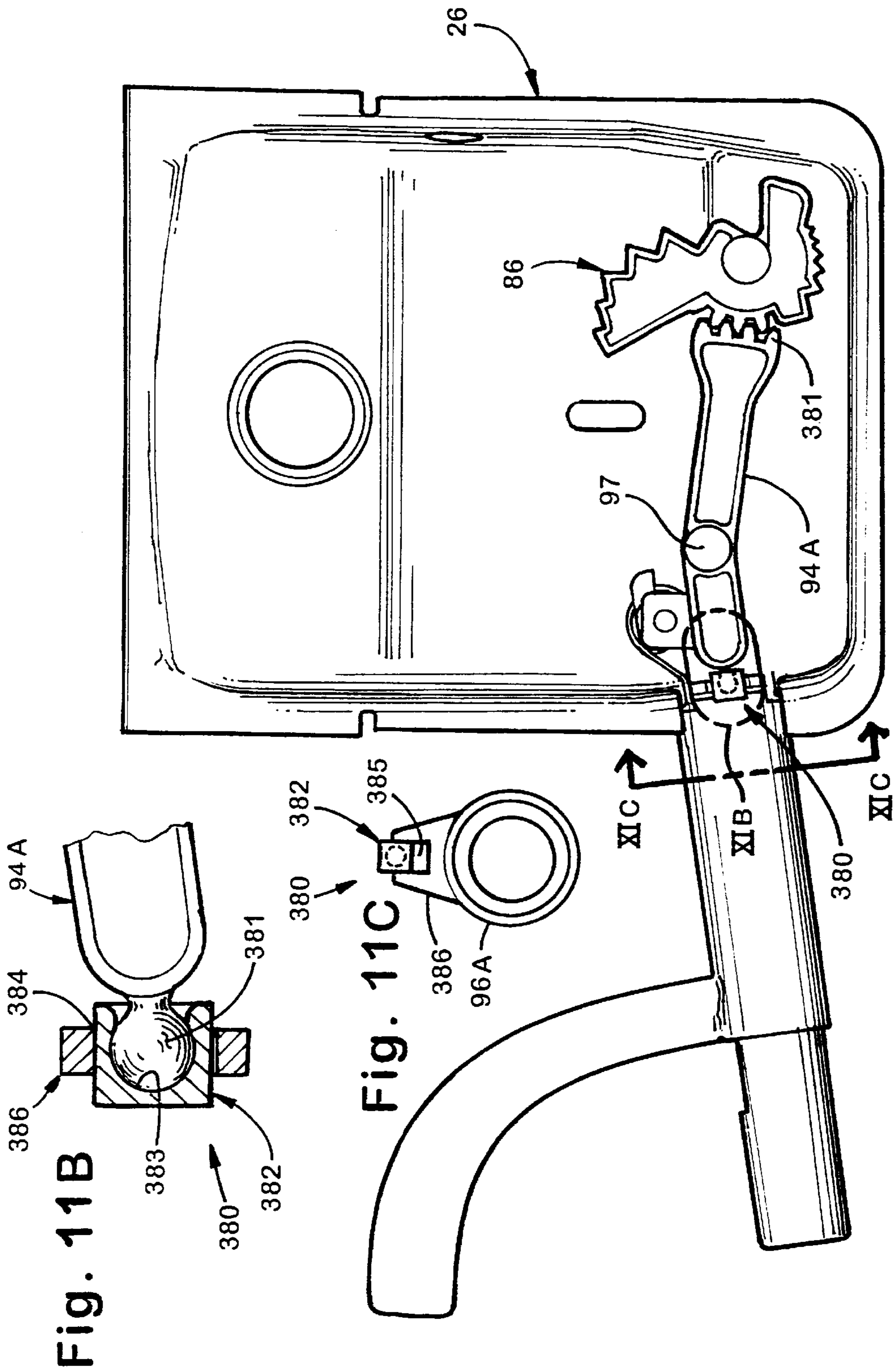
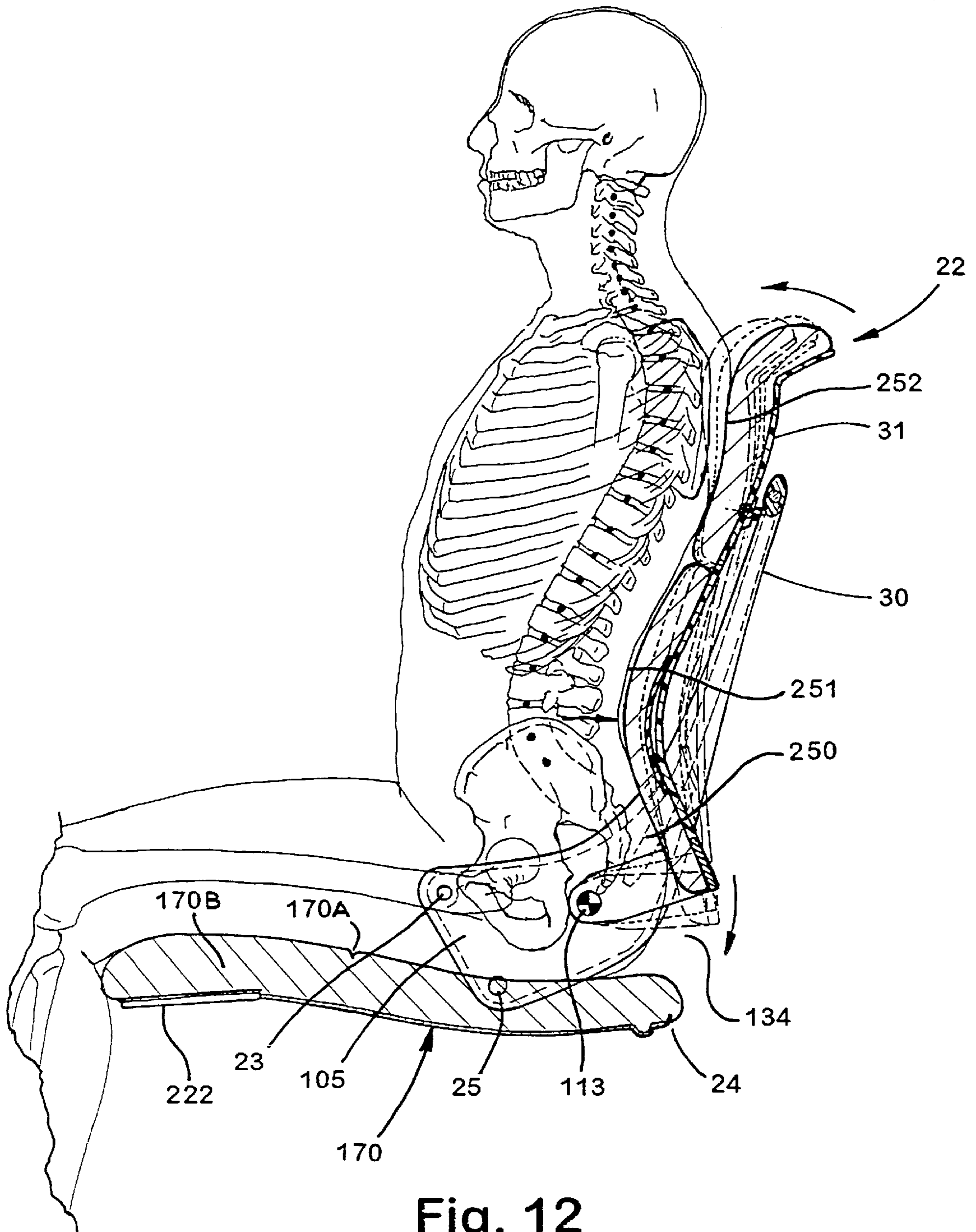


Fig. 11B

Fig. 11C

Fig. 11A



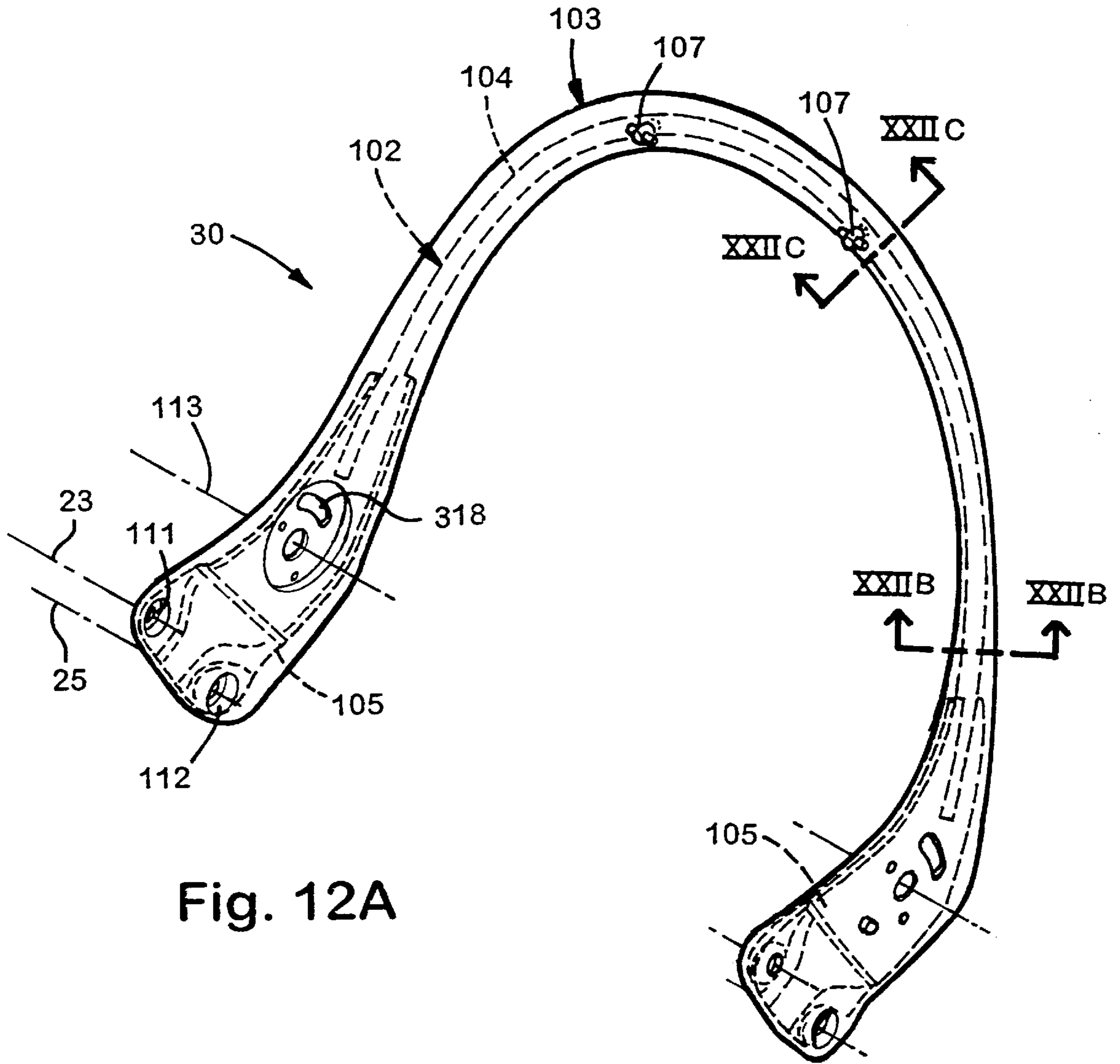


Fig. 12A

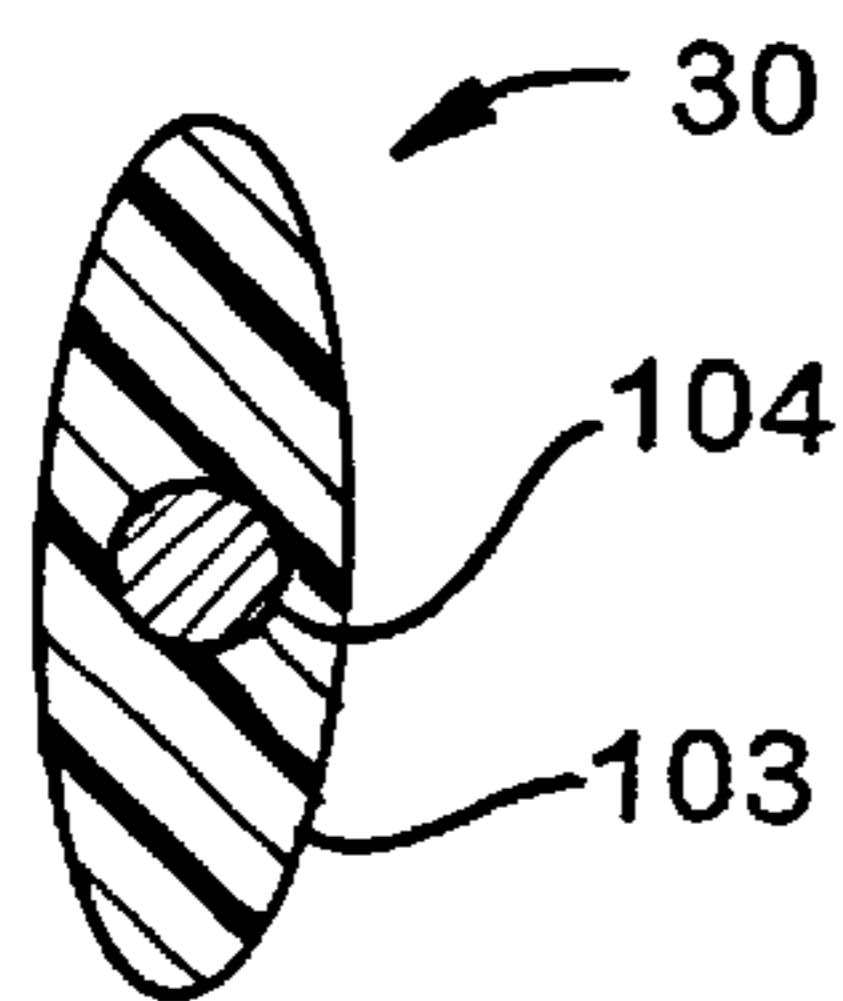


Fig. 12B

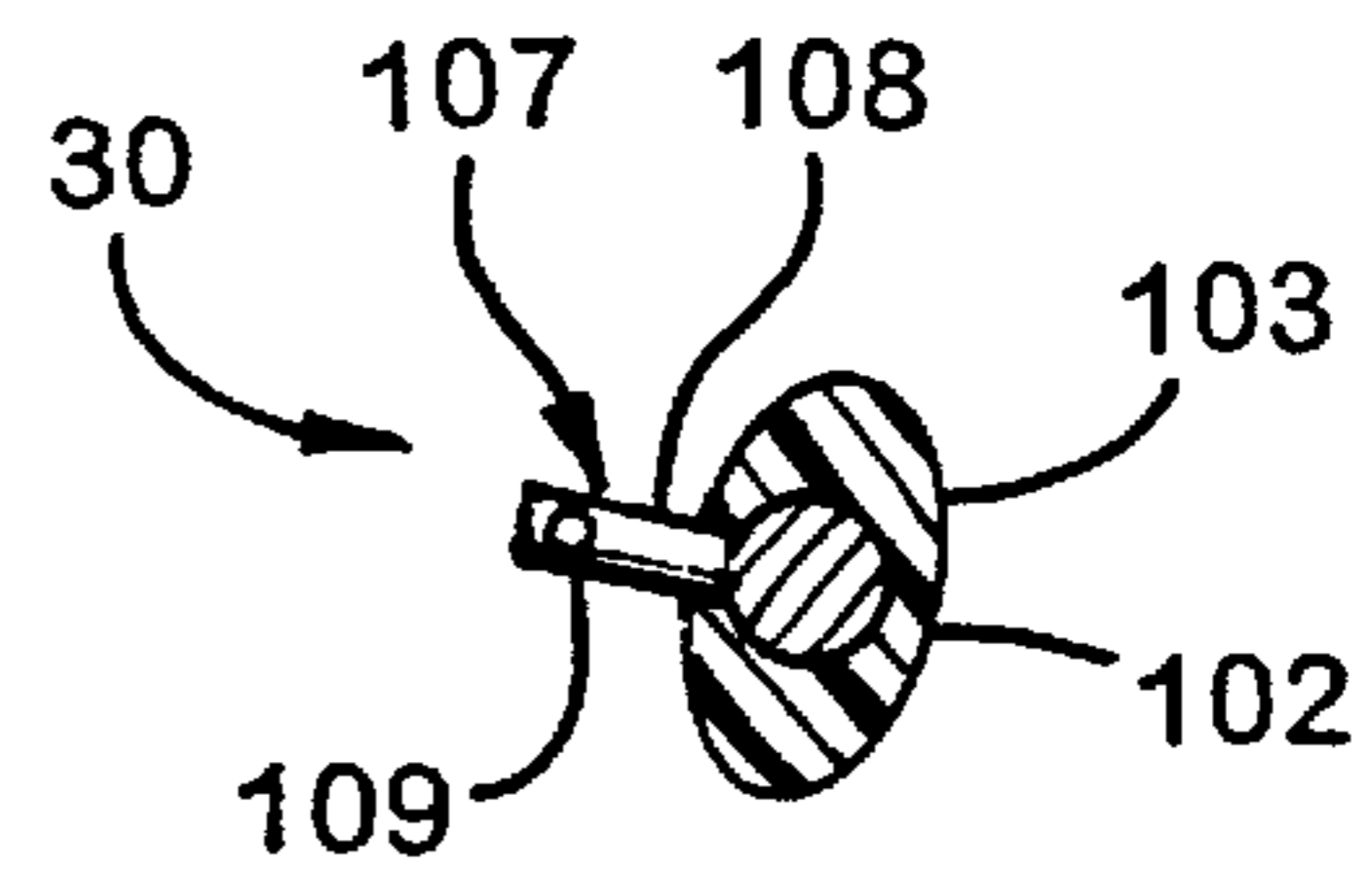


Fig. 12C

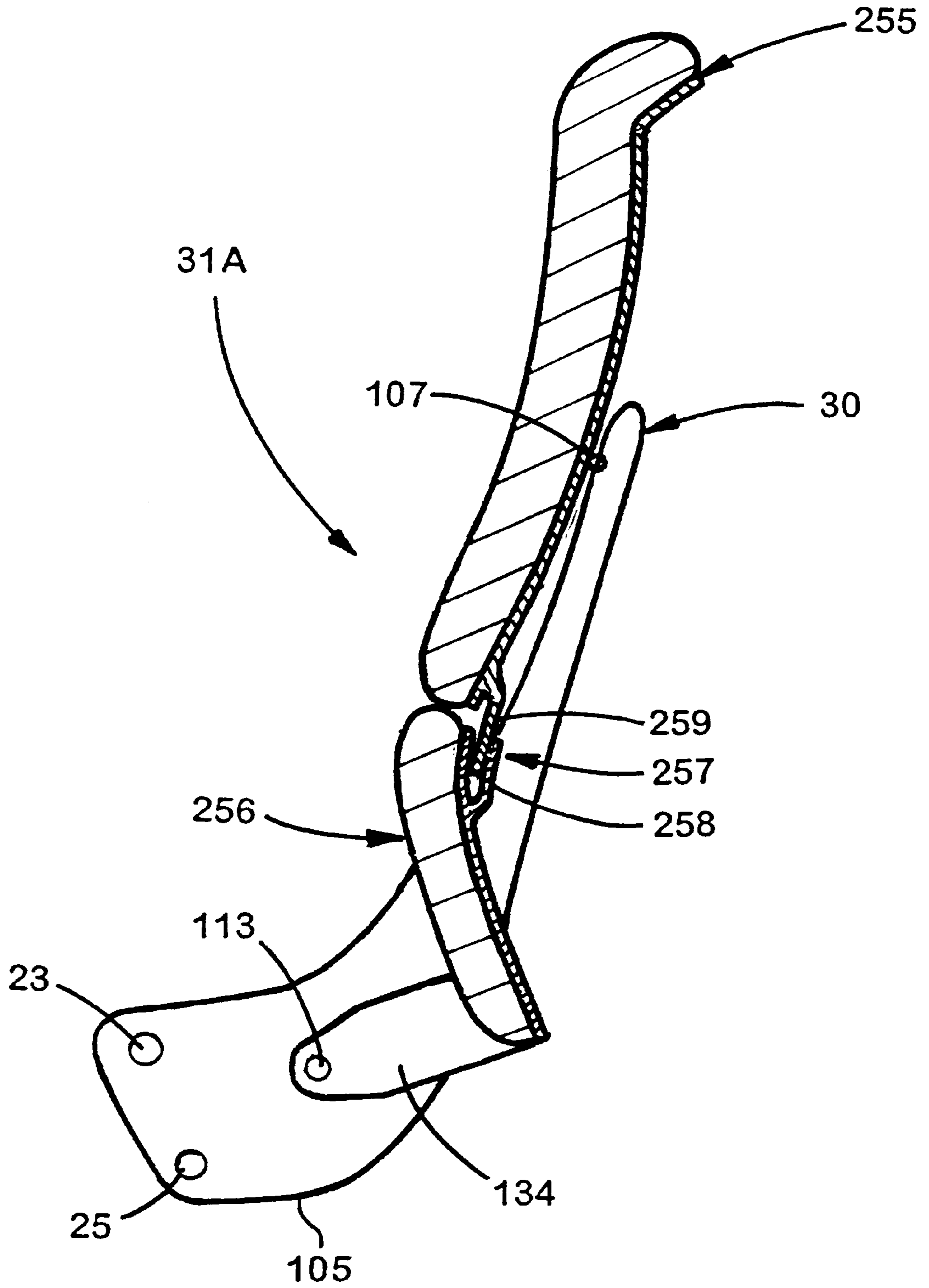


Fig. 12D

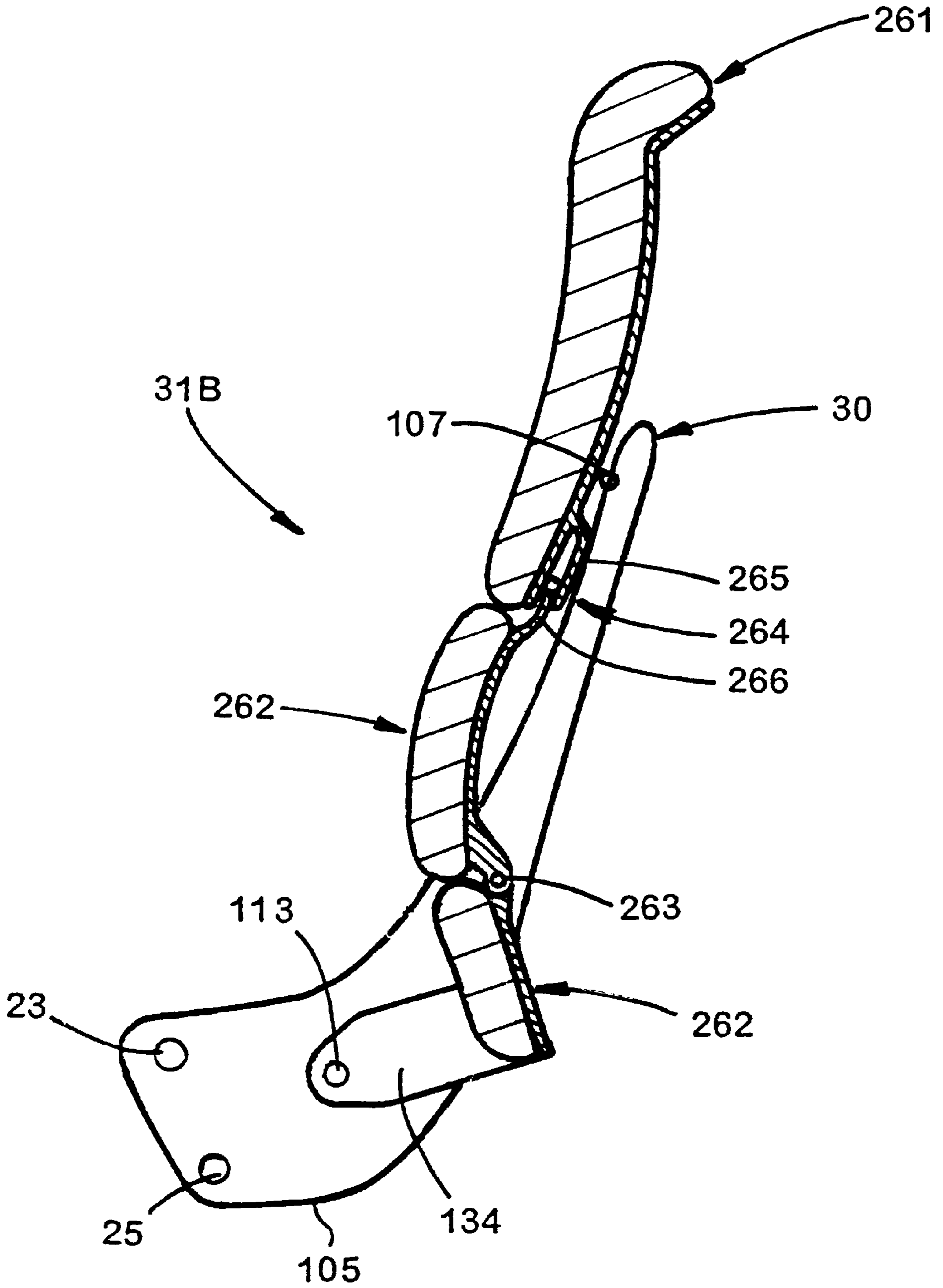
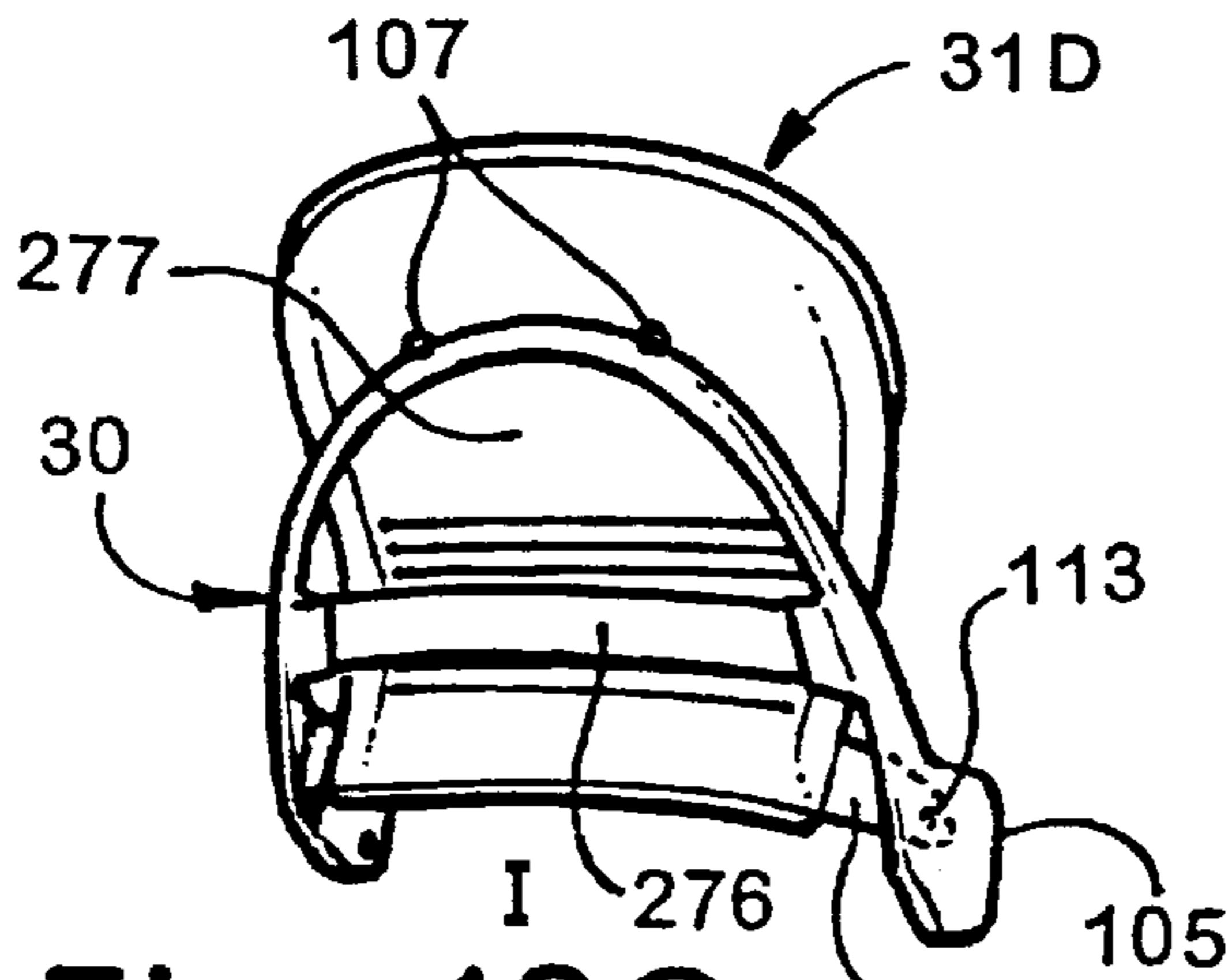
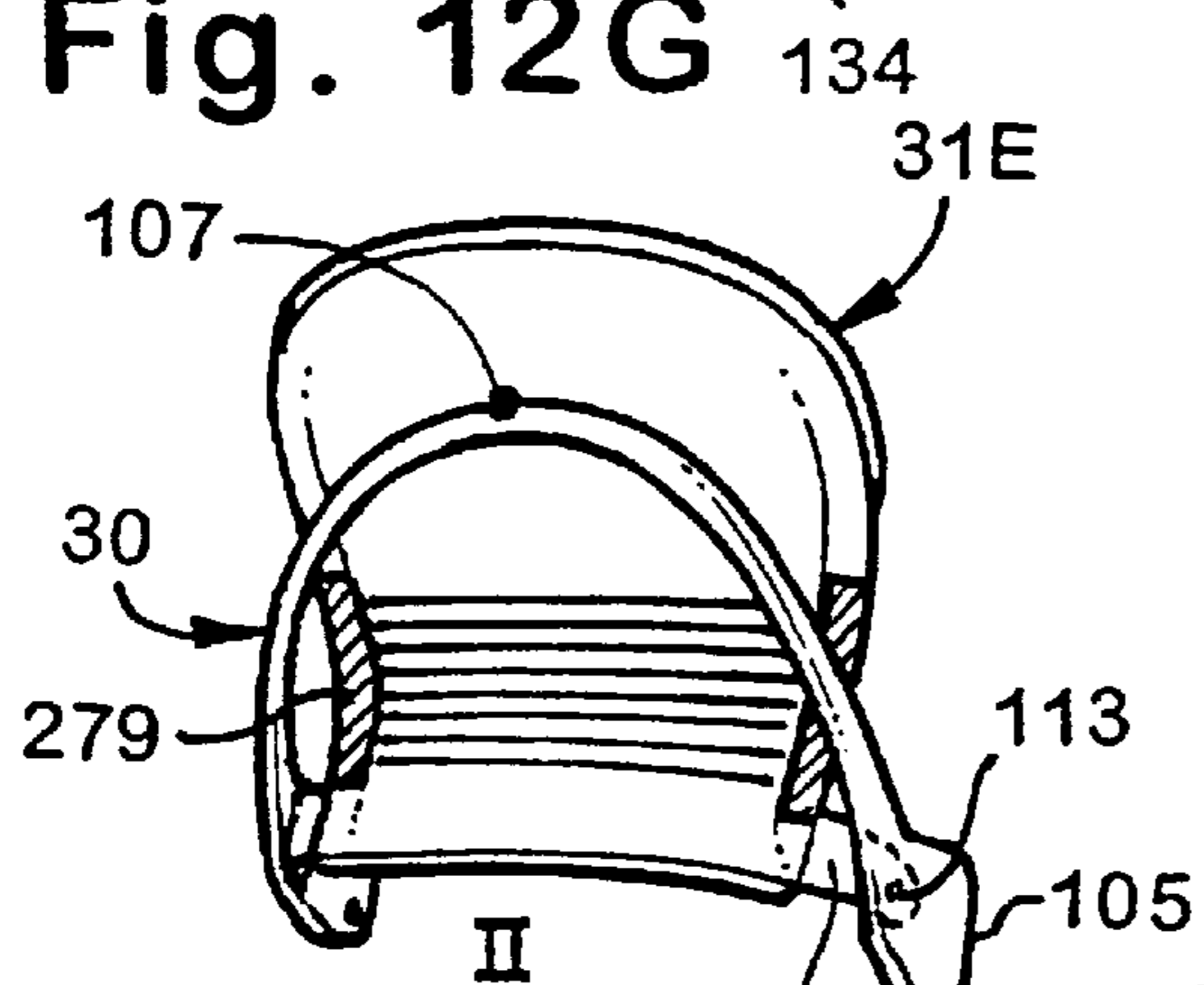


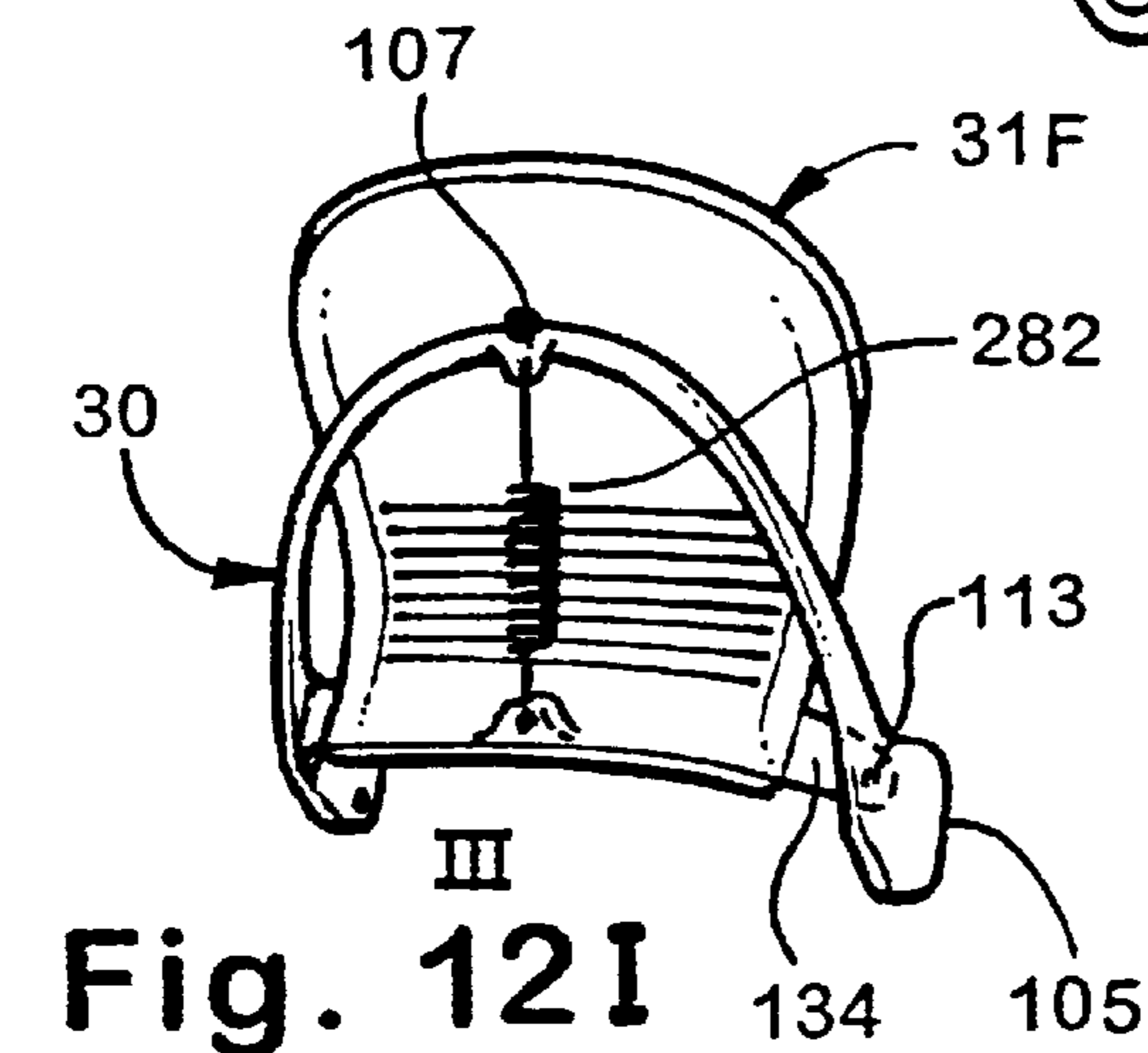
Fig. 12E



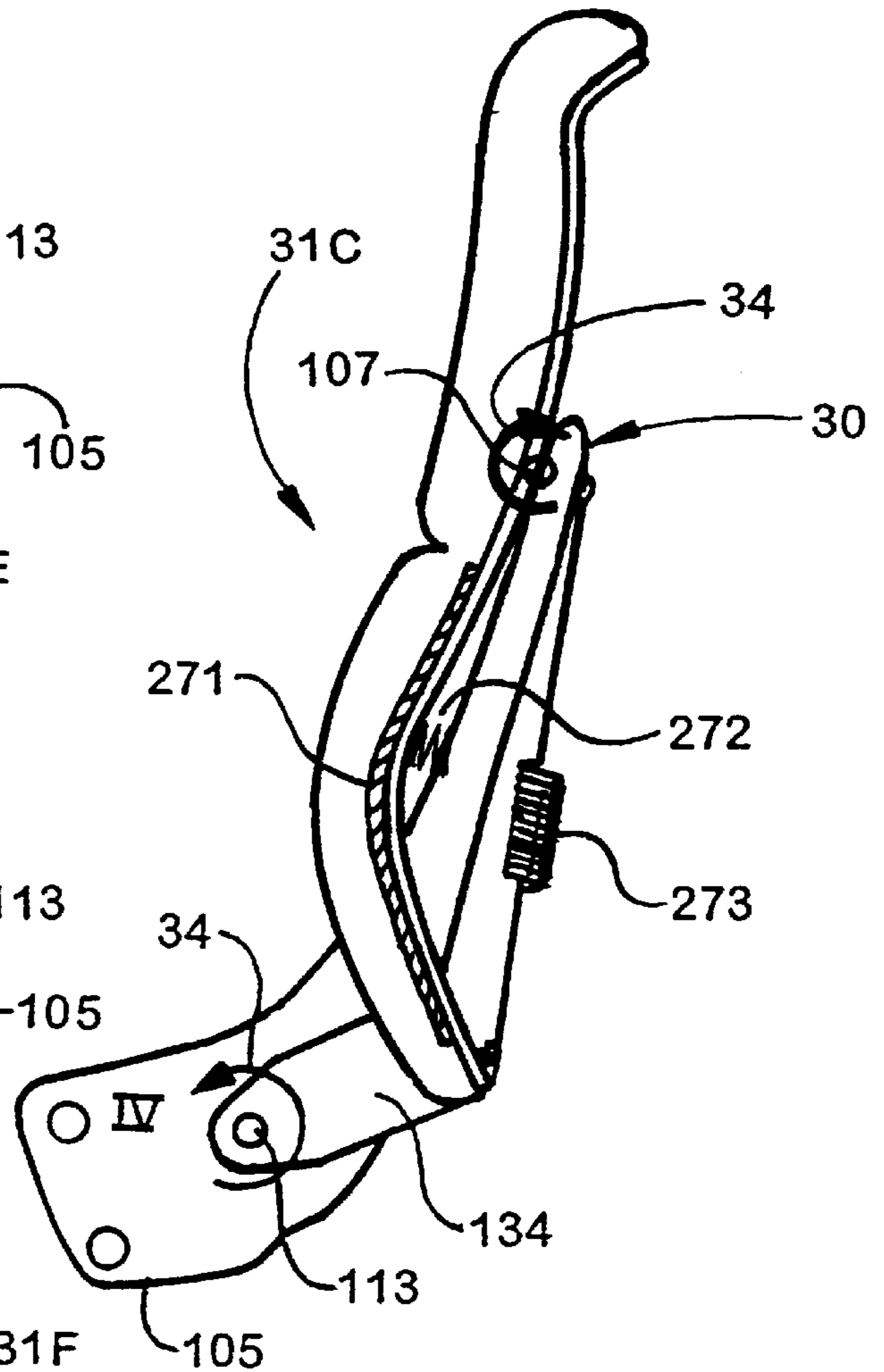
**Fig. 12G**



**Fig. 12H**



**Fig. 12I**



**Fig. 12F**





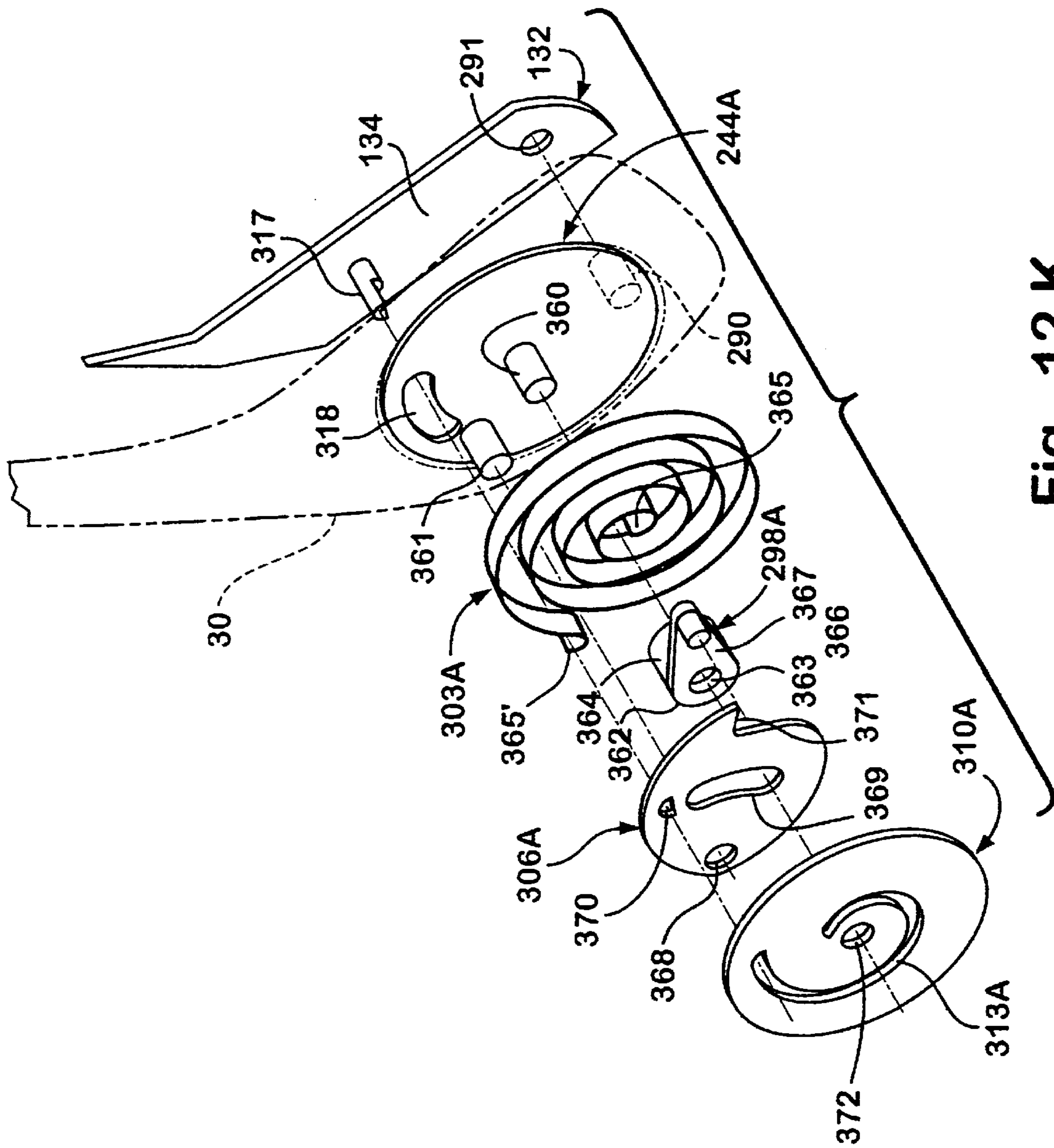


Fig. 12 K

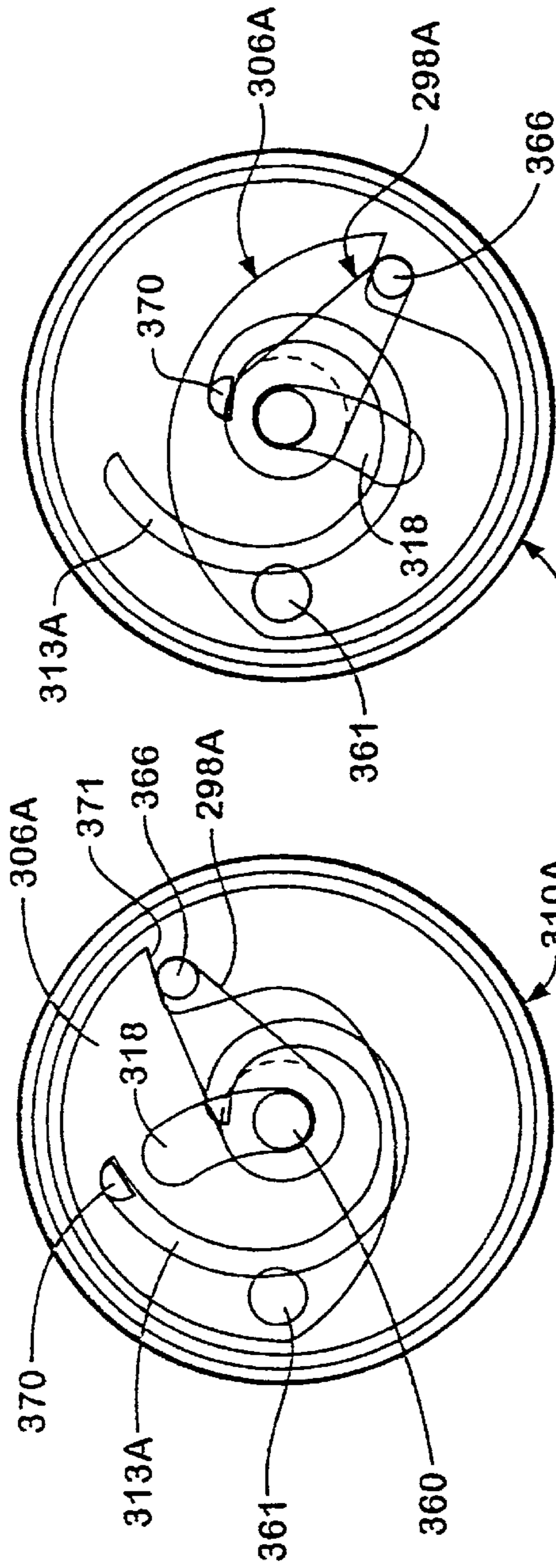


Fig. 12 L

LOW TORQUE

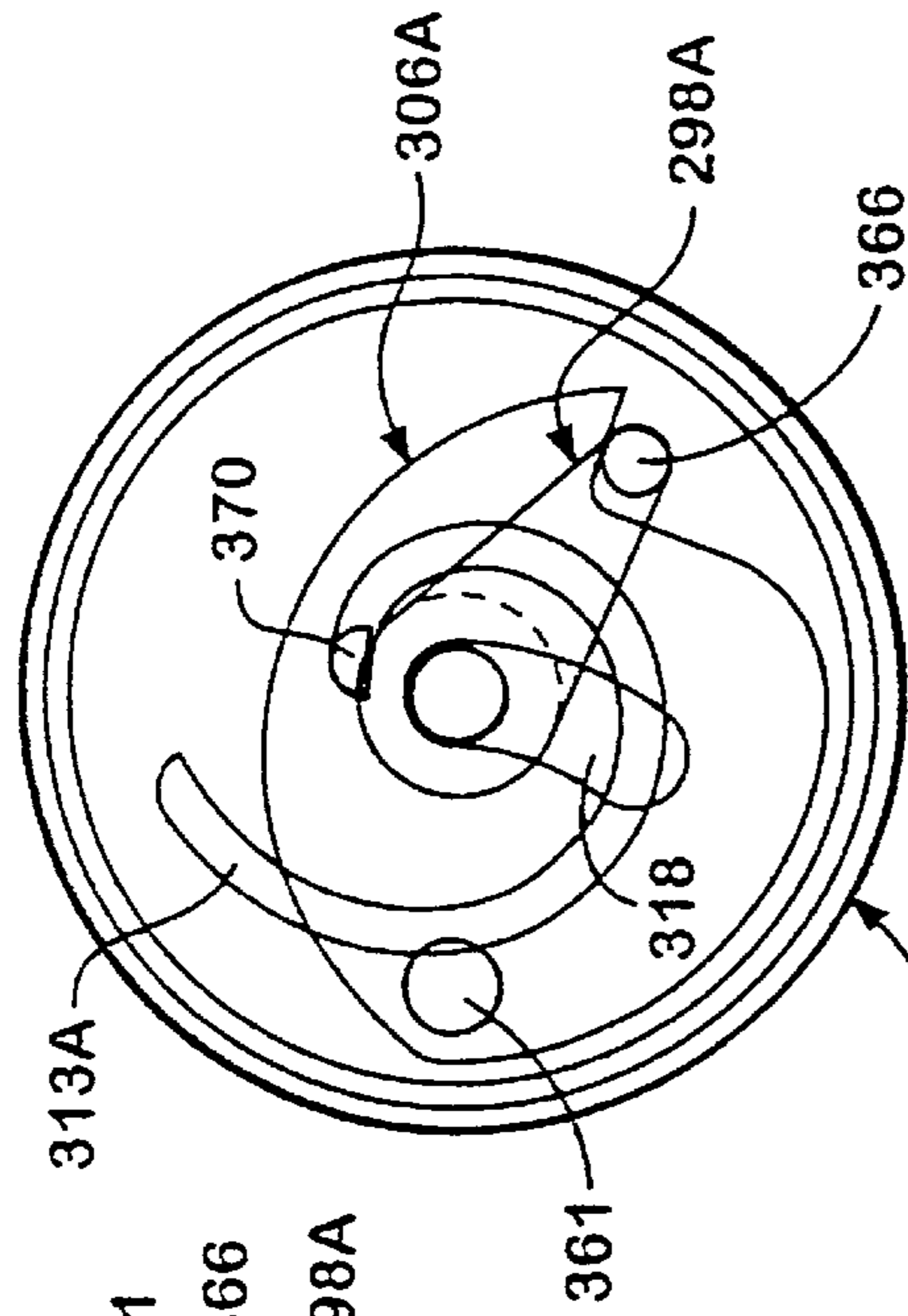


Fig. 12 M

HIGH TORQUE

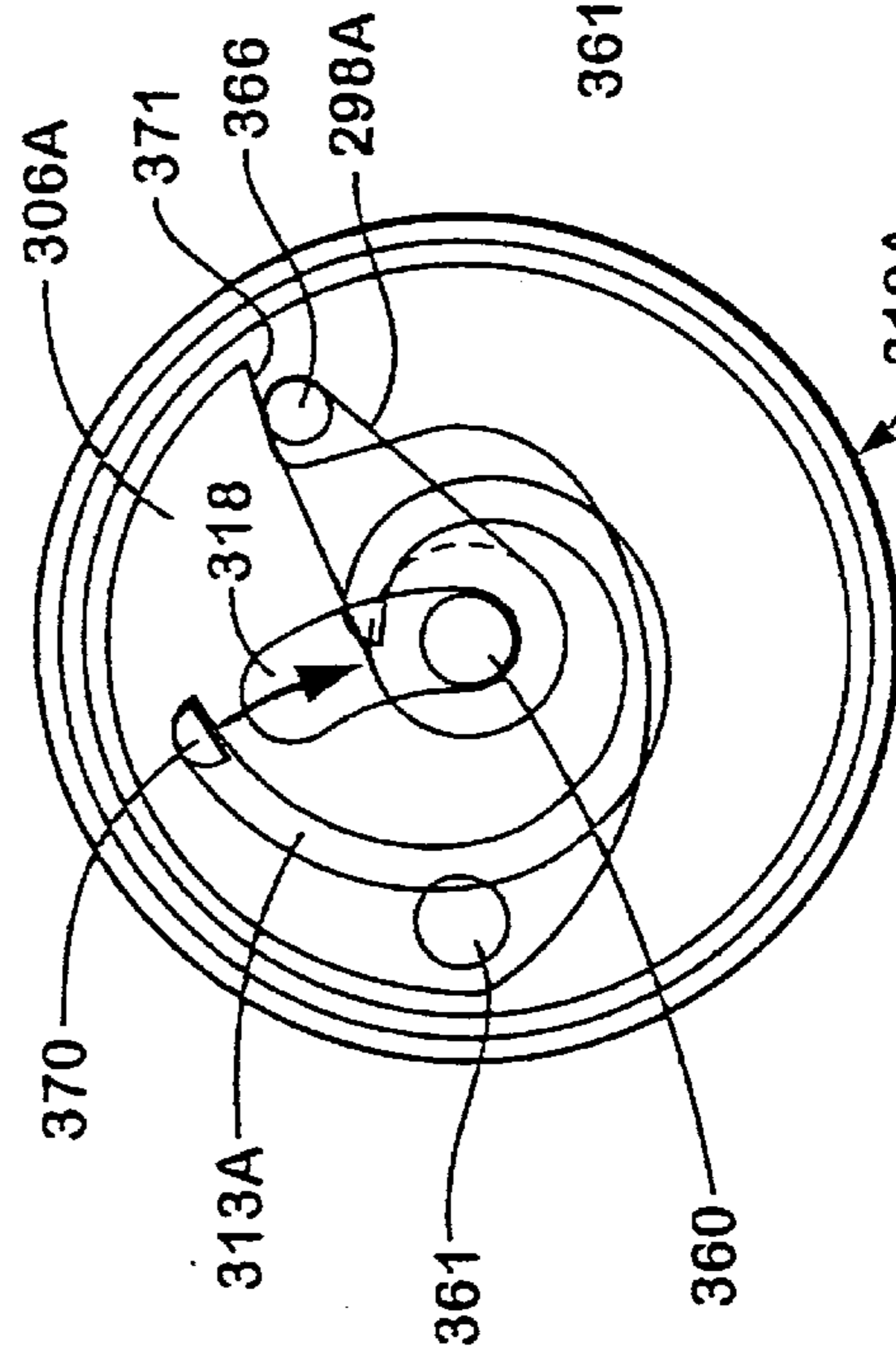


Fig. 12 LL

LOW TORQUE

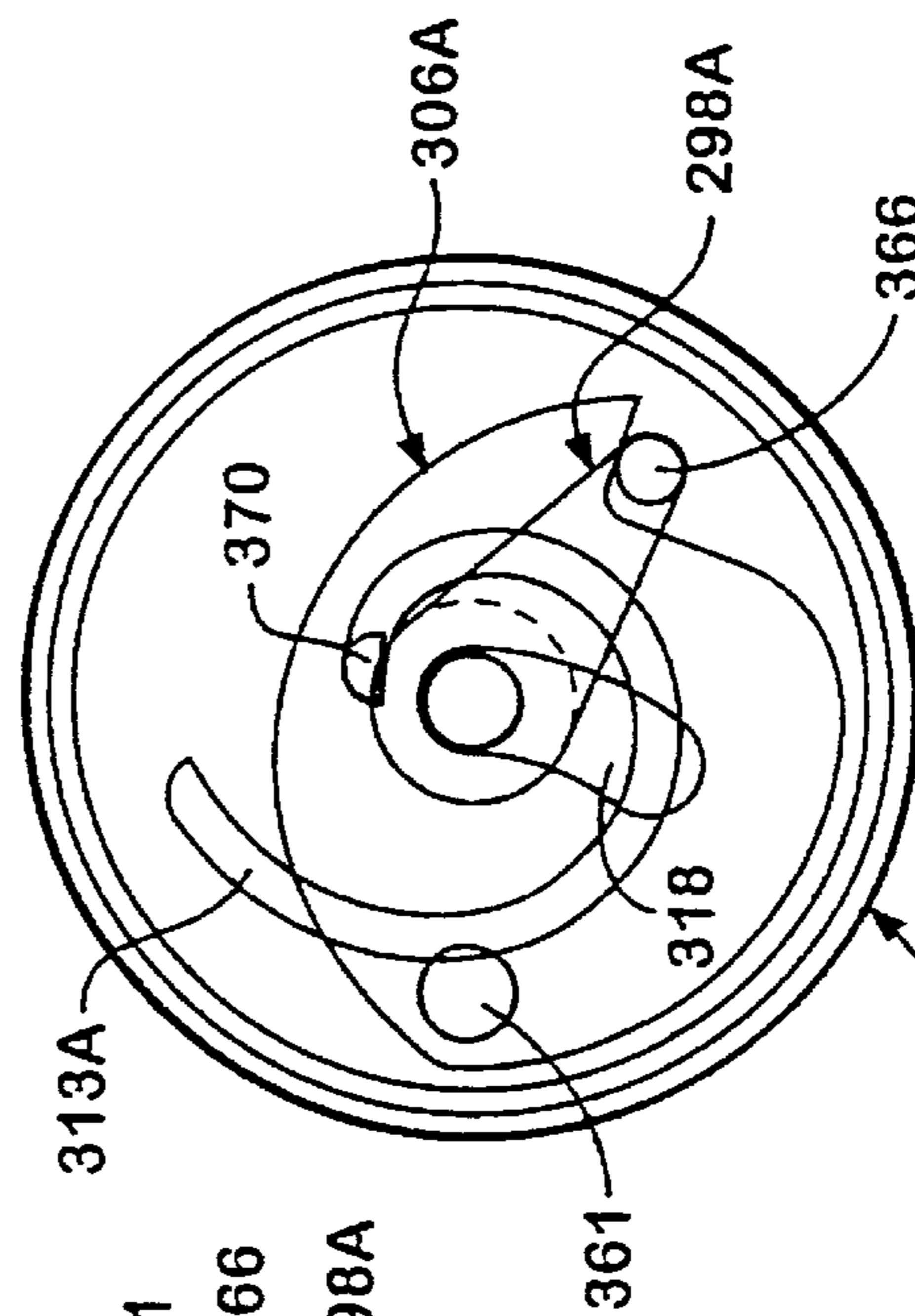


Fig. 12 MM

HIGH TORQUE

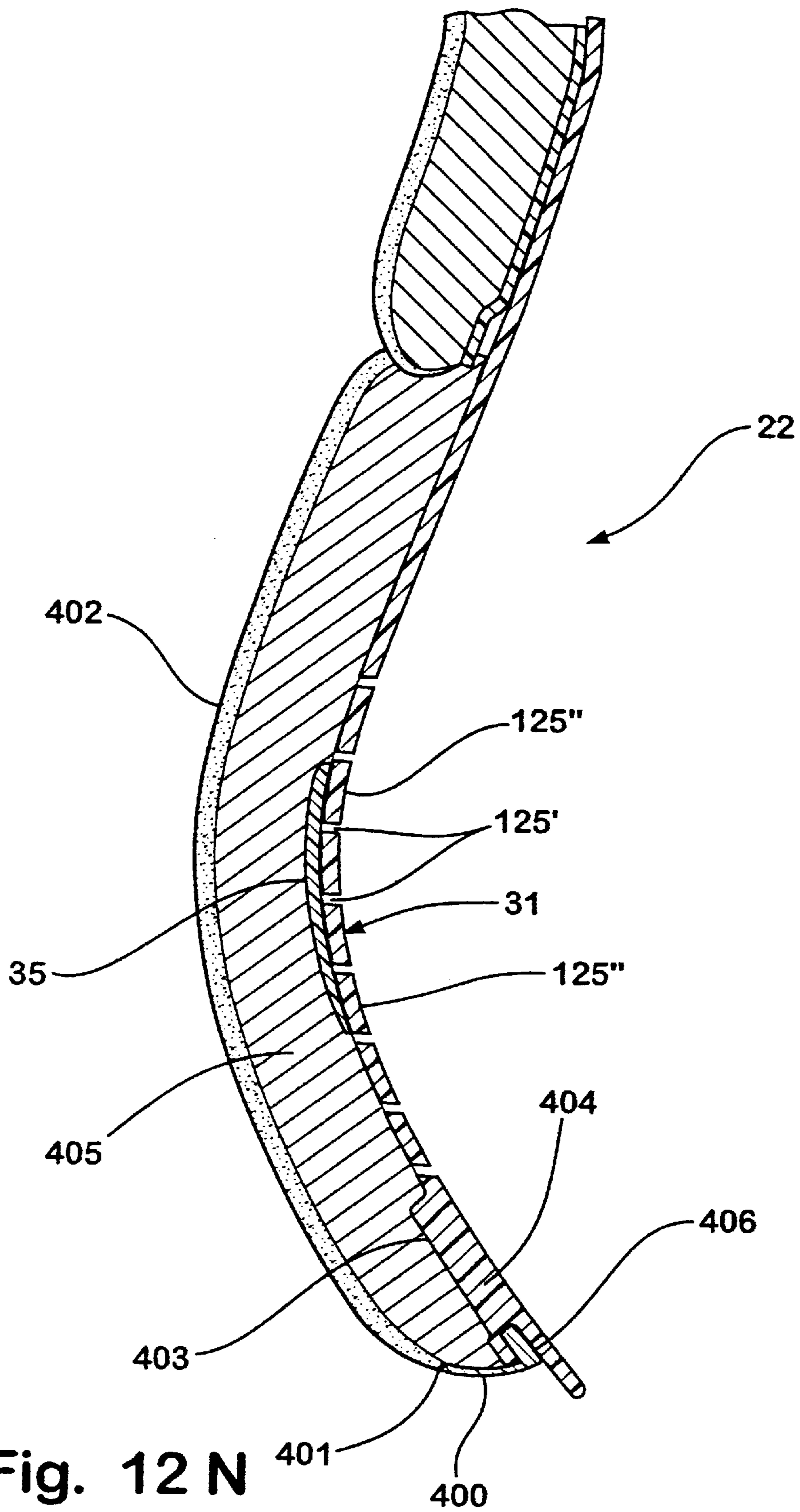


Fig. 12 N

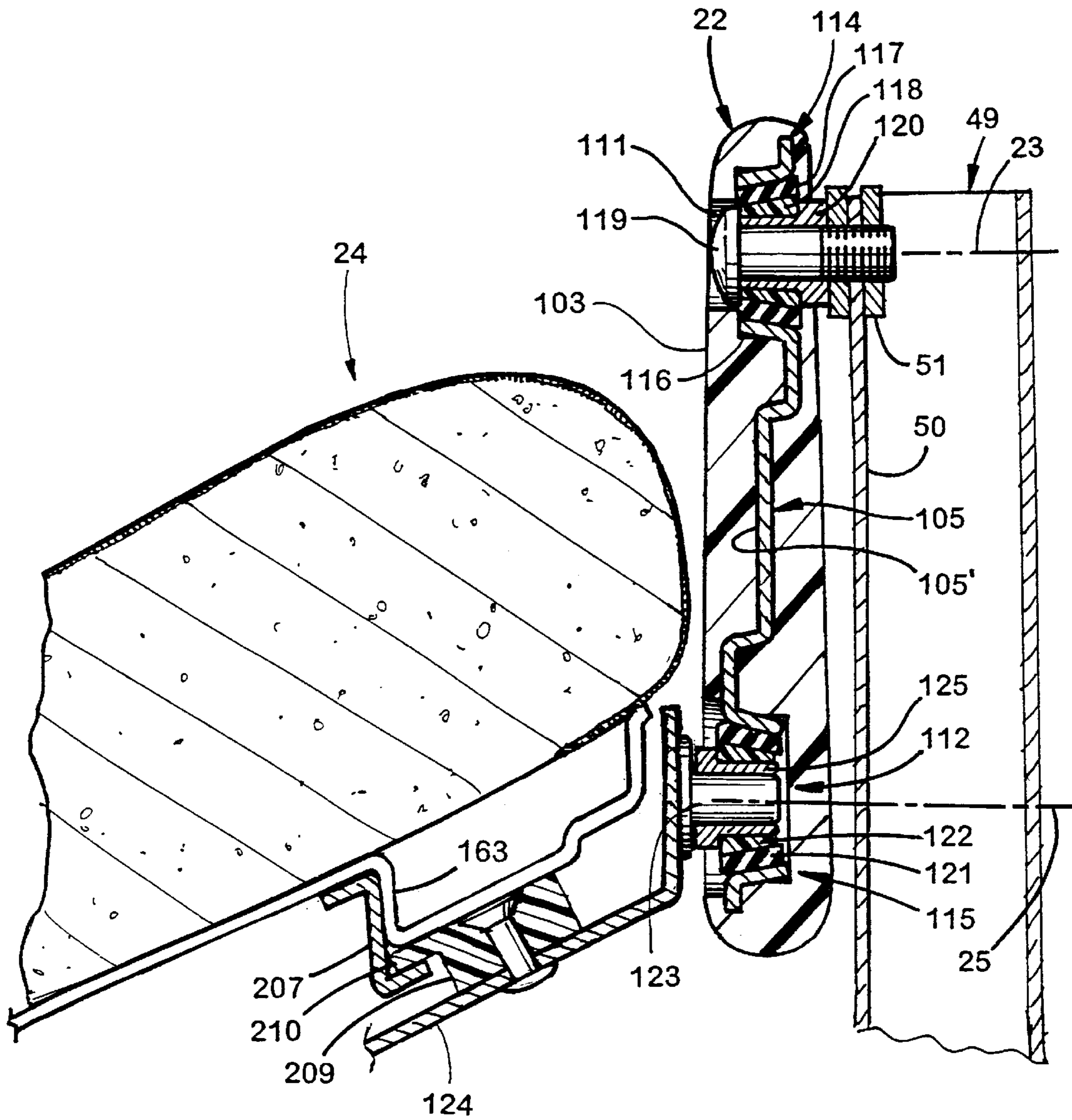


Fig. 13

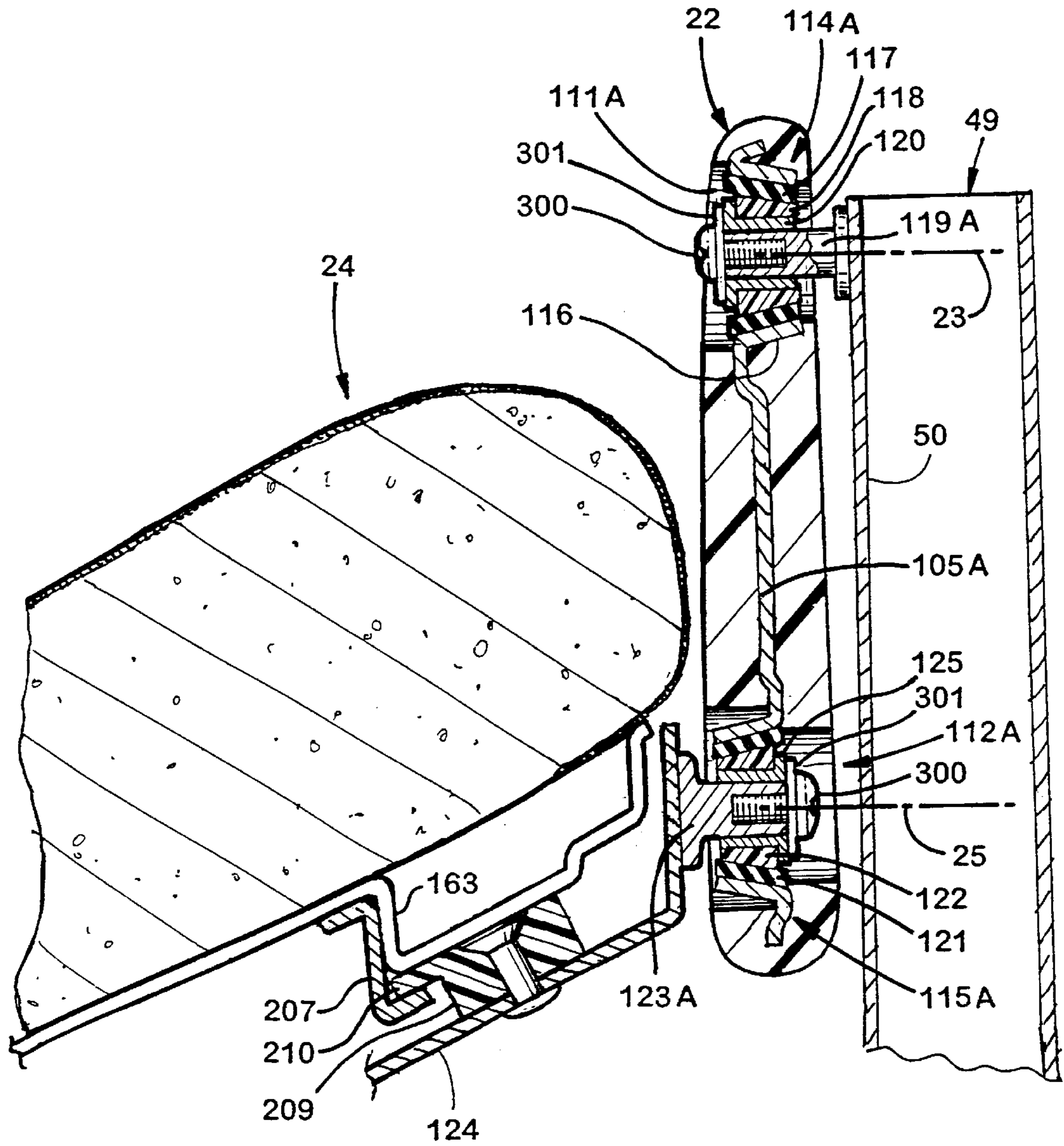


Fig. 13A

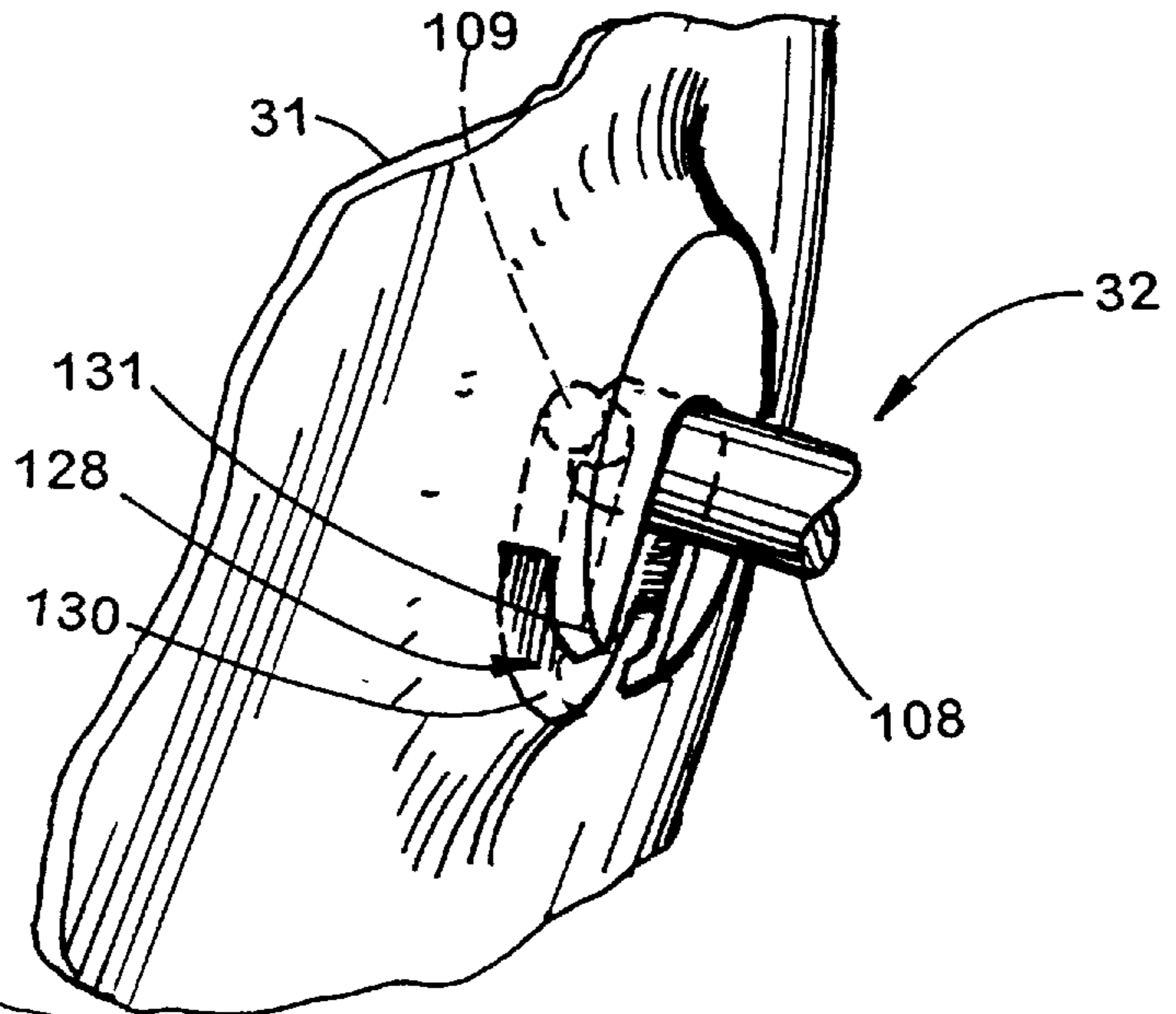


Fig. 14A

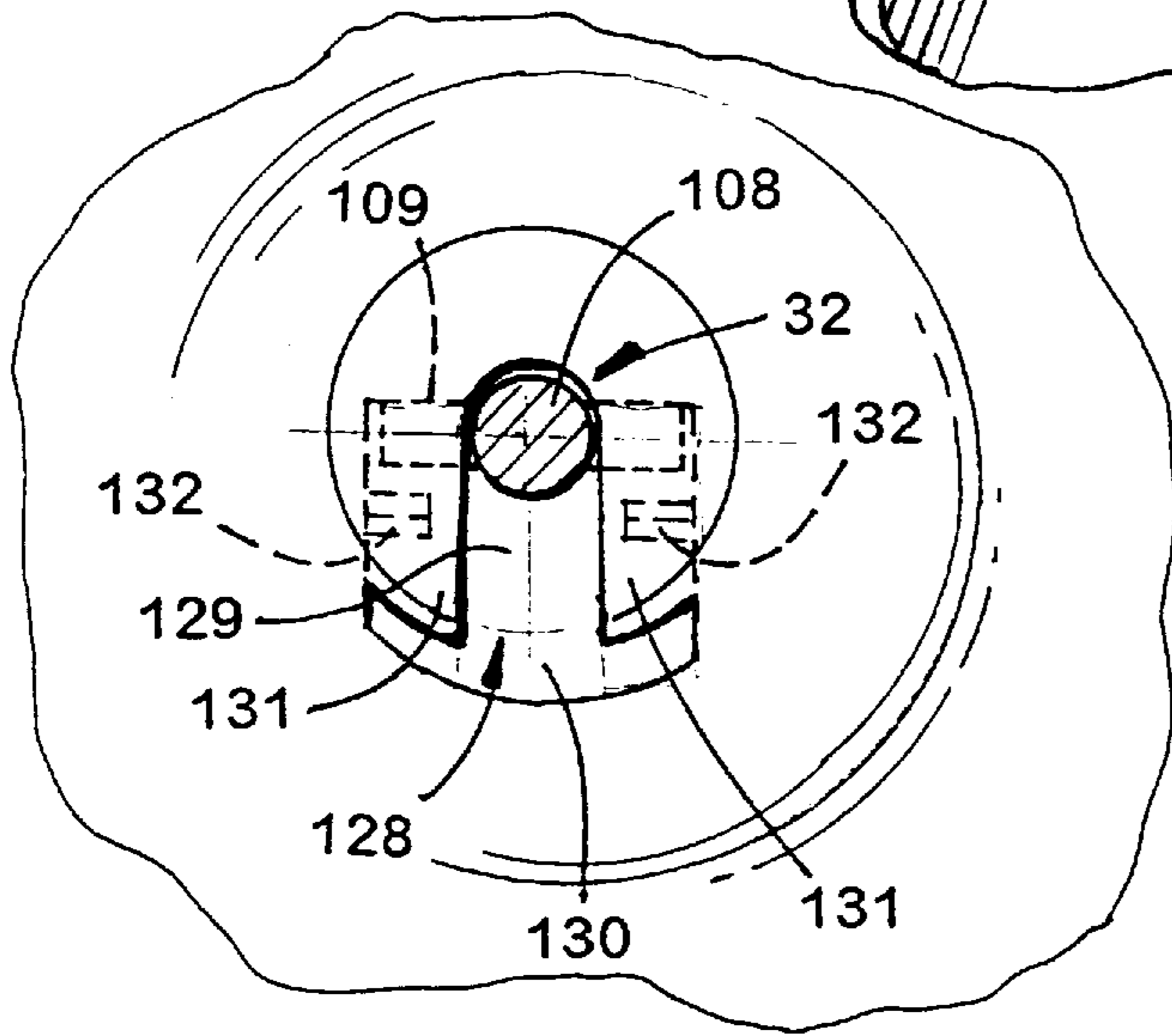


Fig. 14B

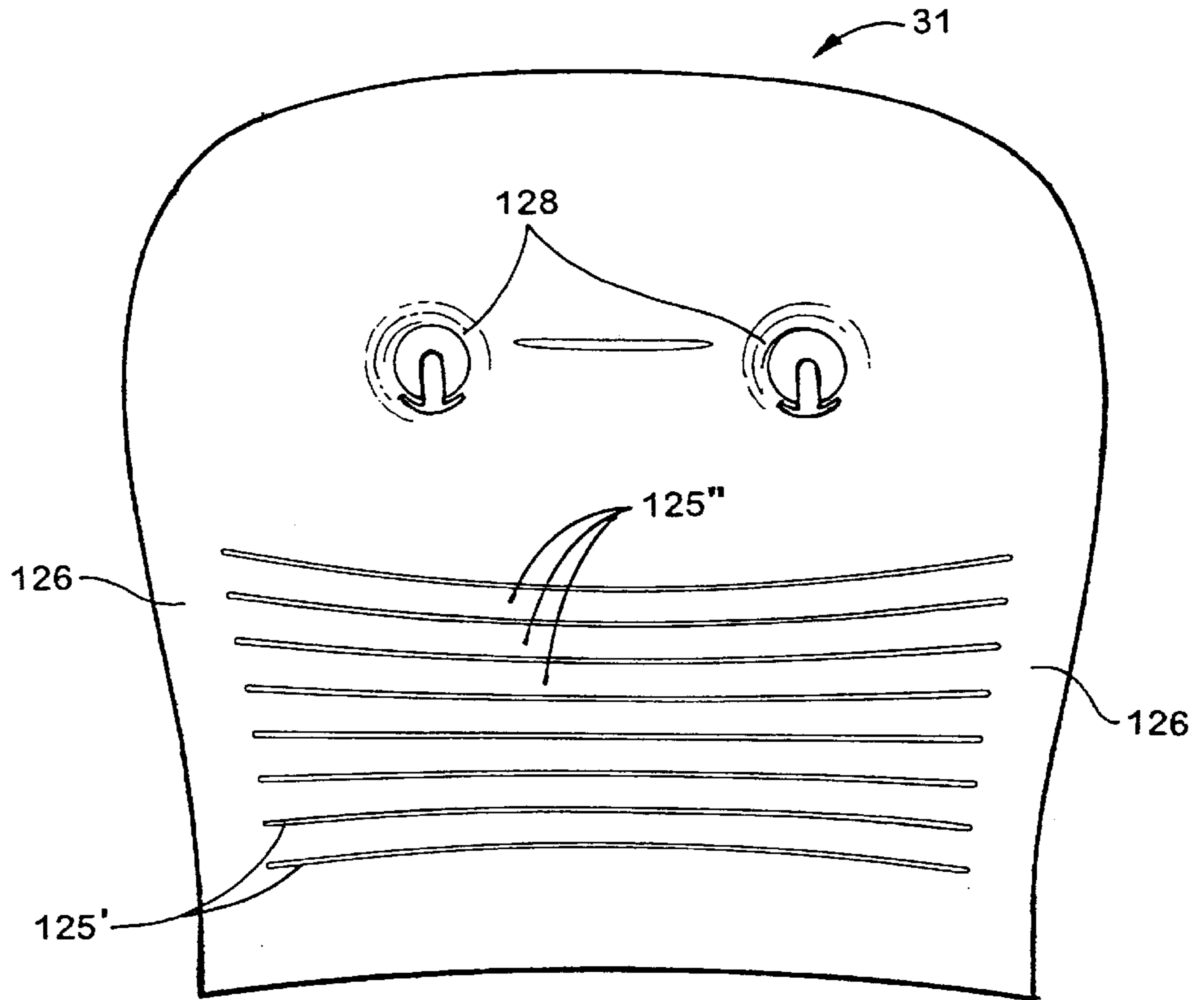


Fig. 15

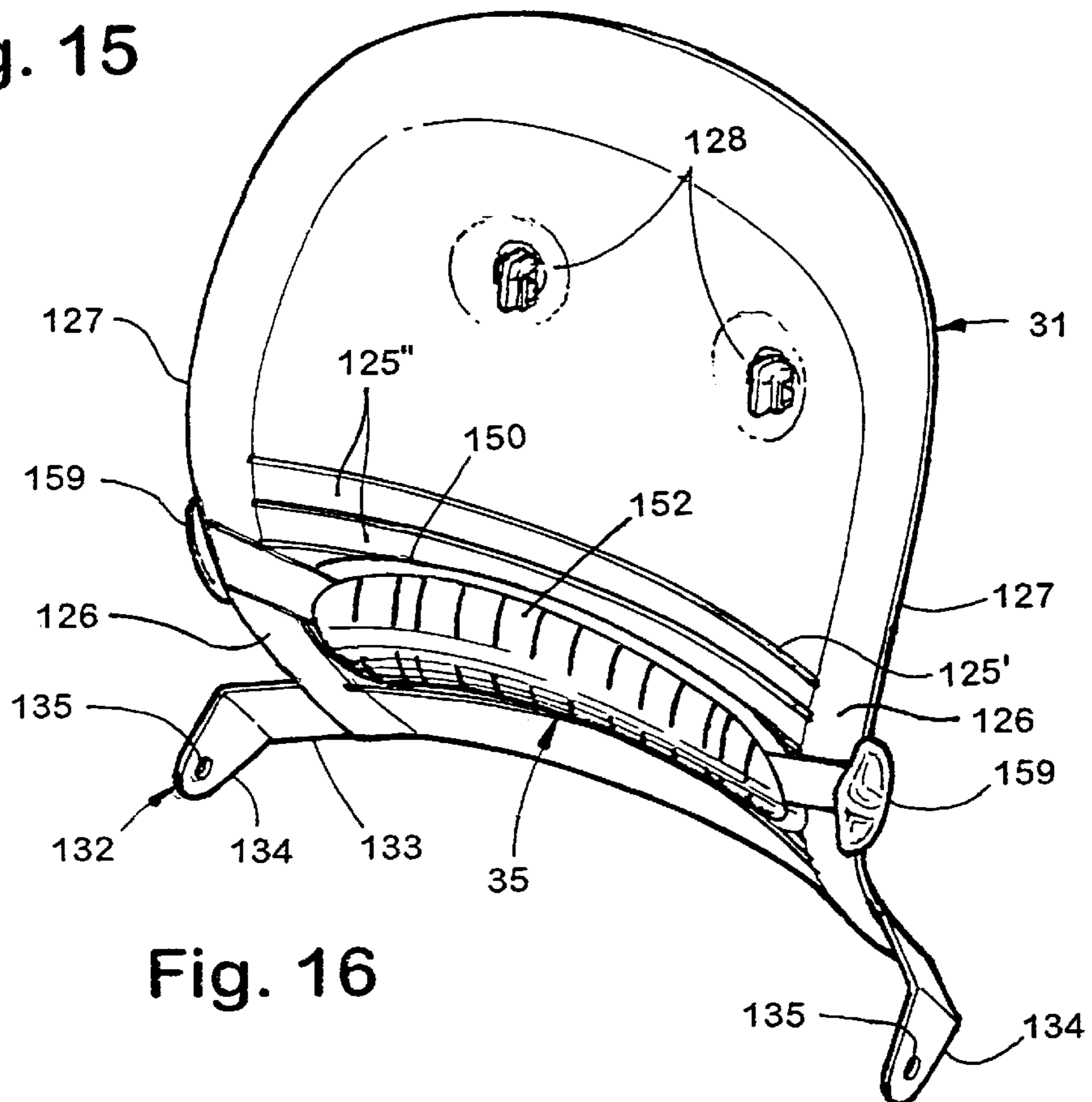


Fig. 16



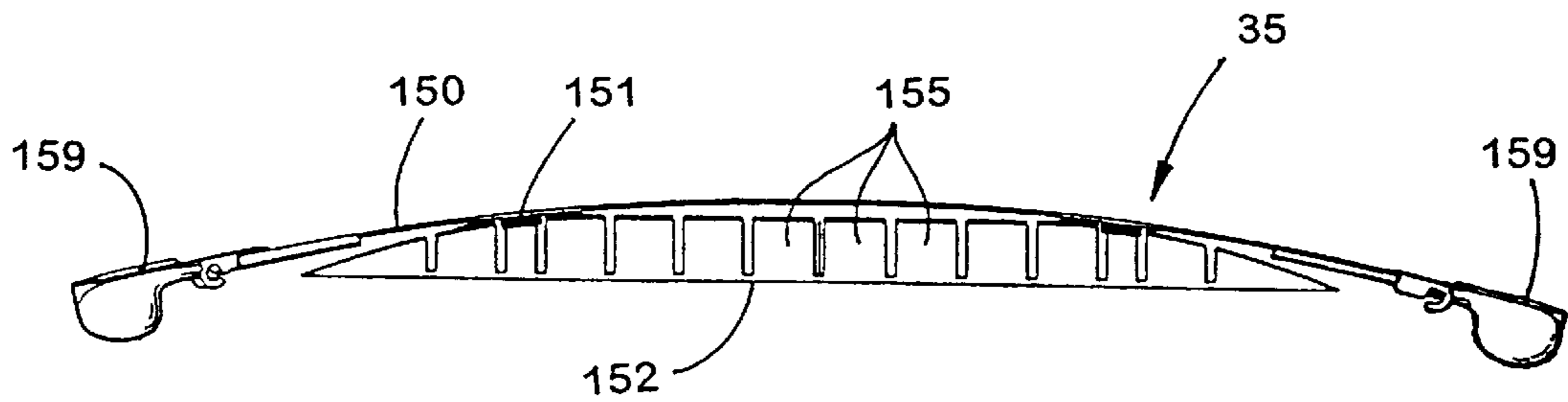


Fig. 17

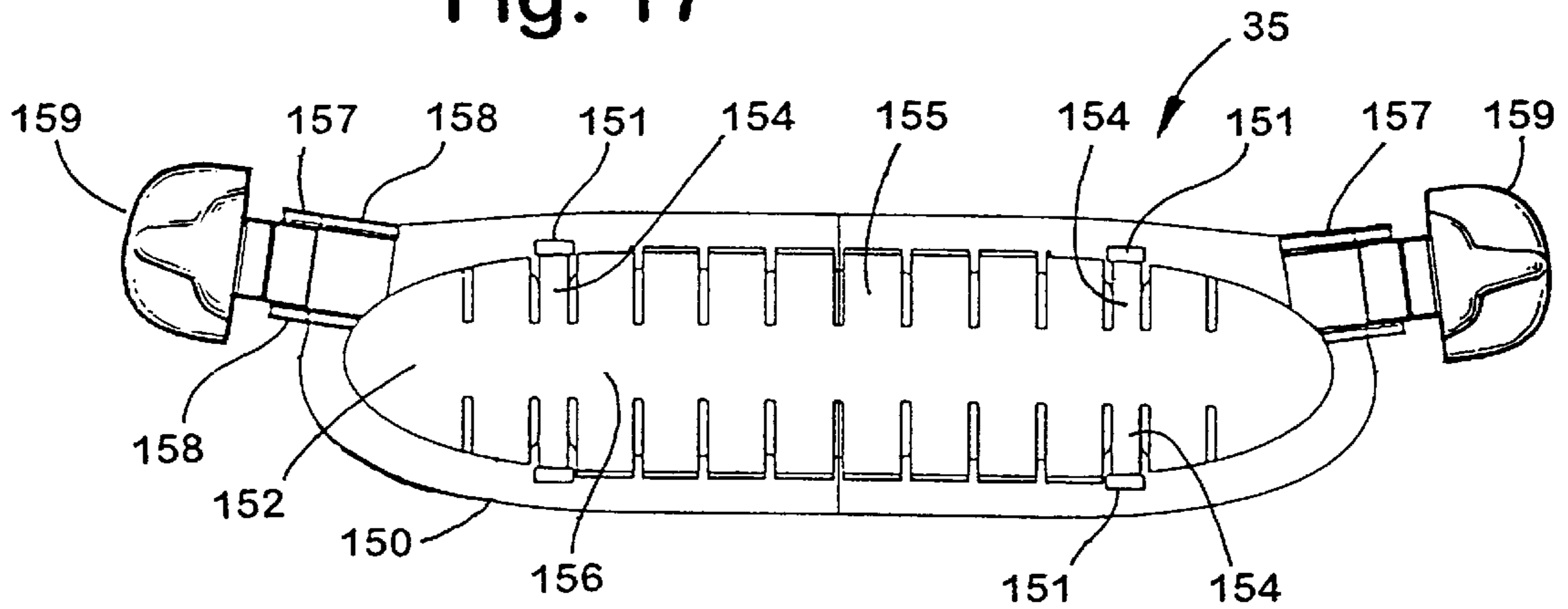


Fig. 18

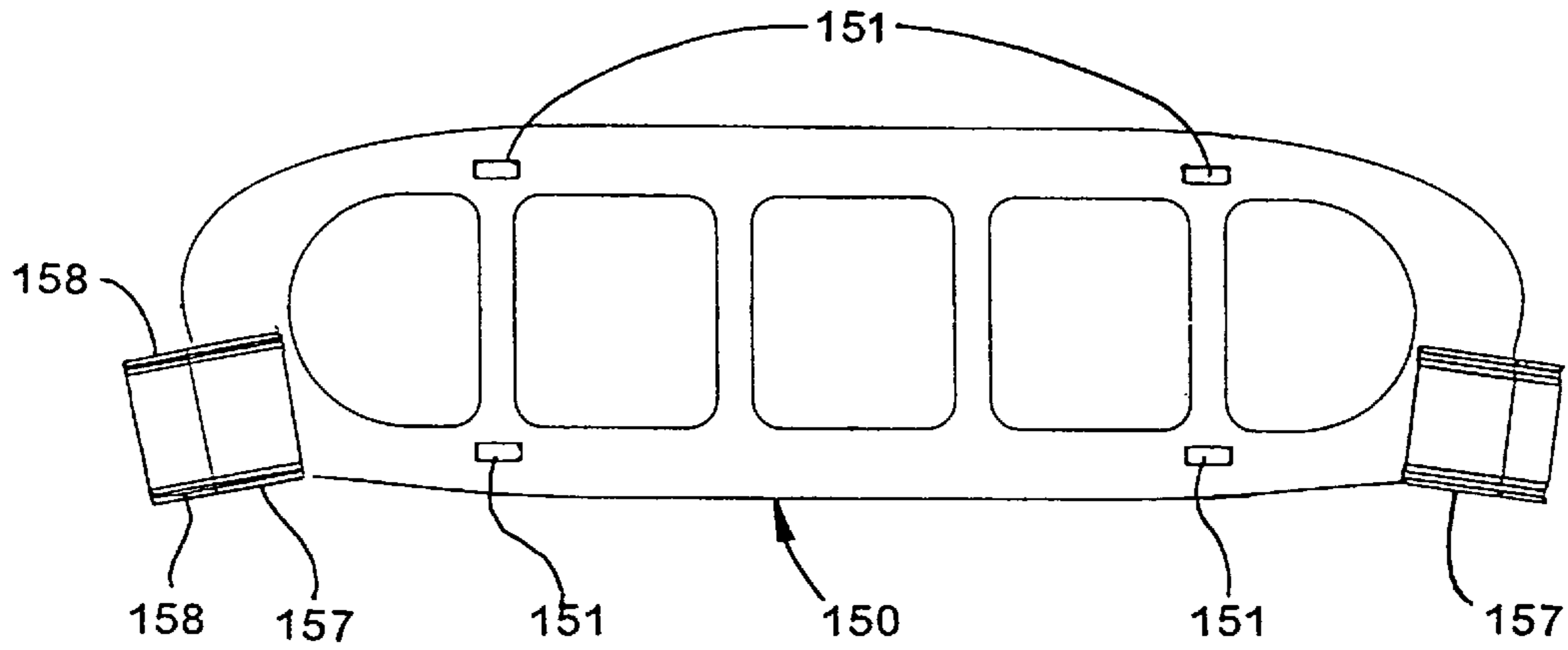


Fig. 19

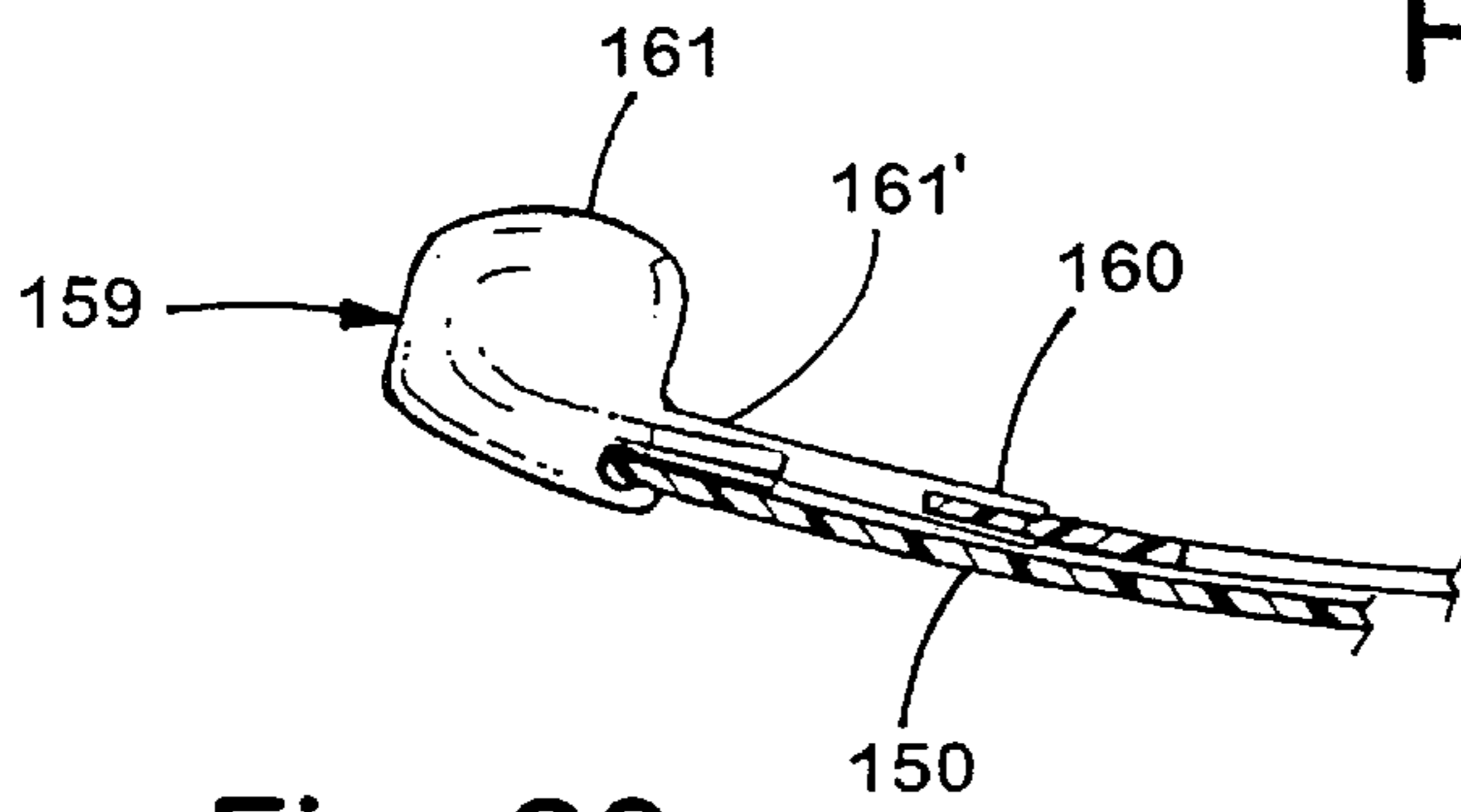


Fig. 20

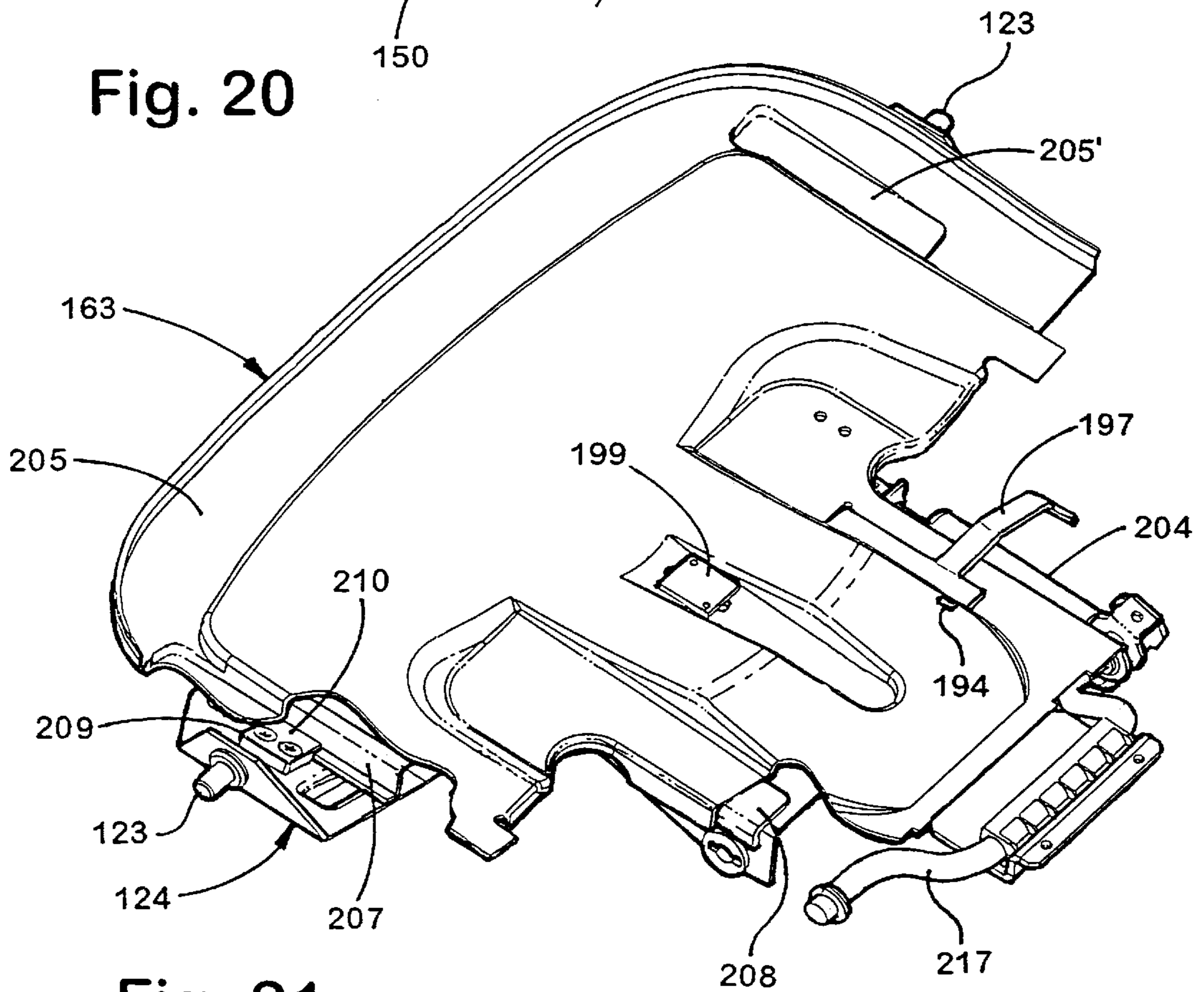


Fig. 21

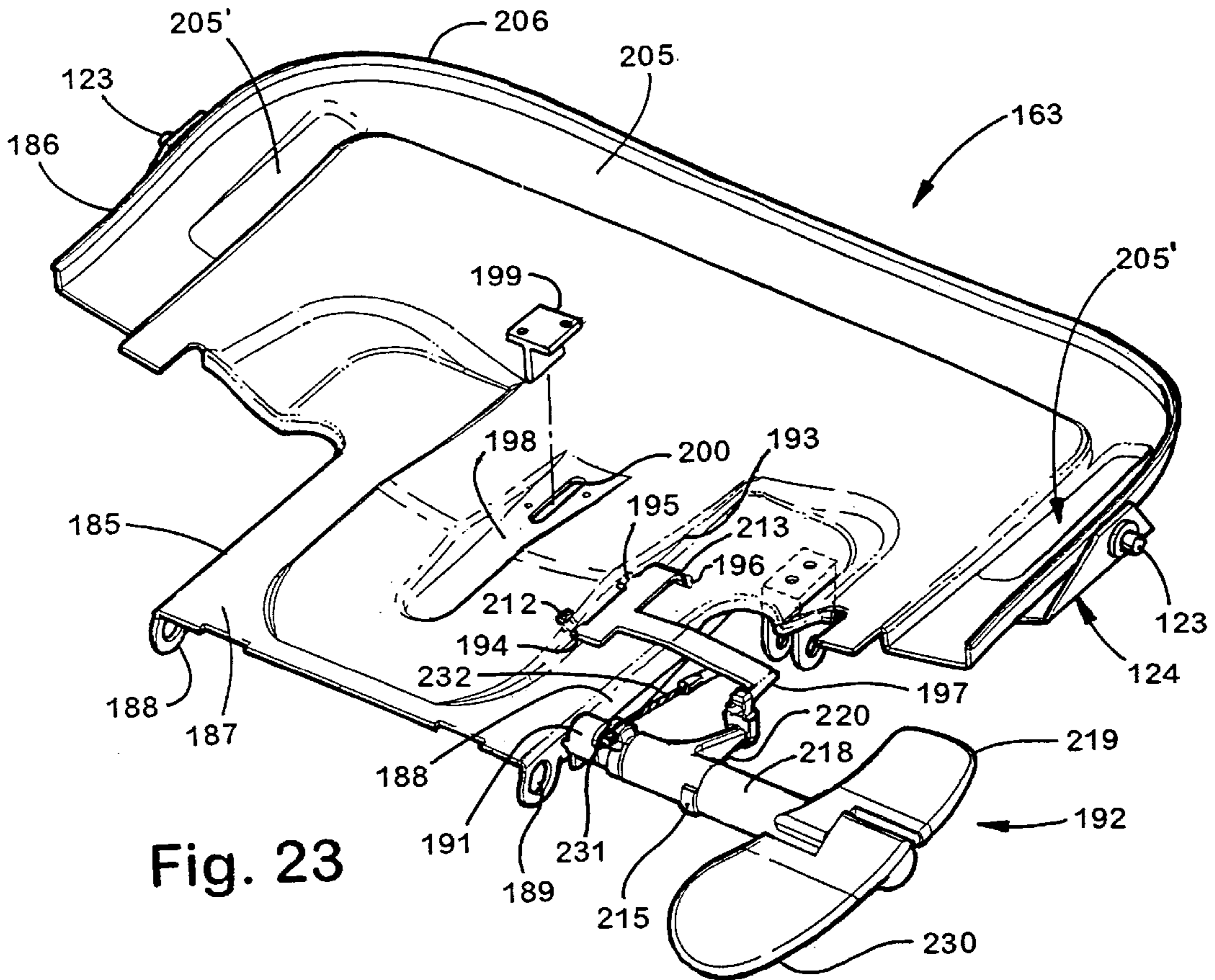


Fig. 23

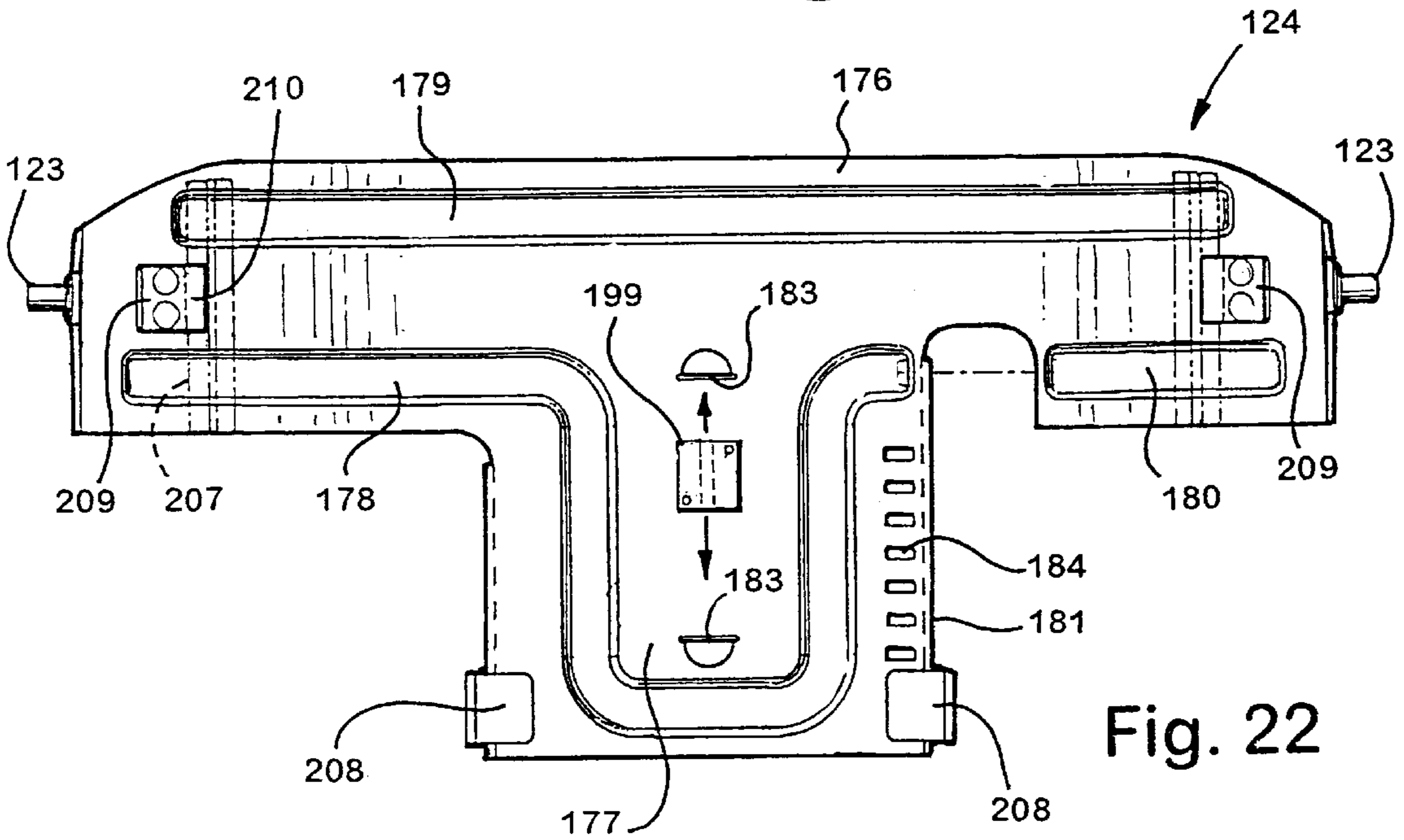


Fig. 22

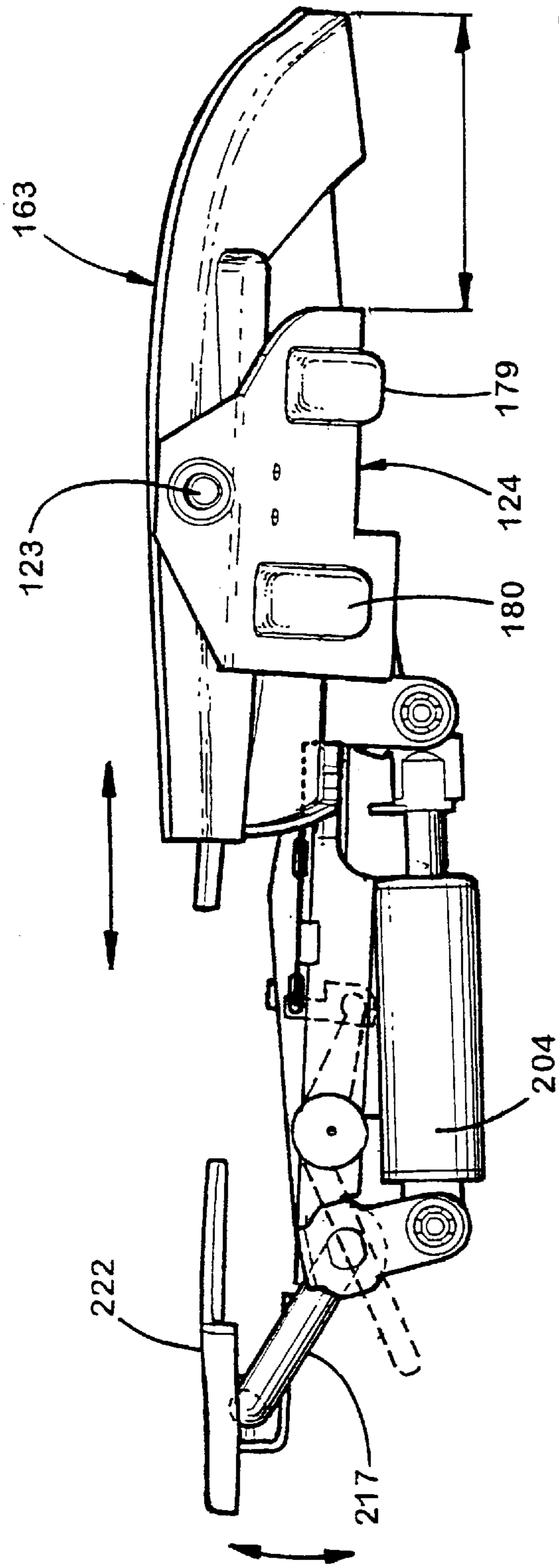


Fig. 24

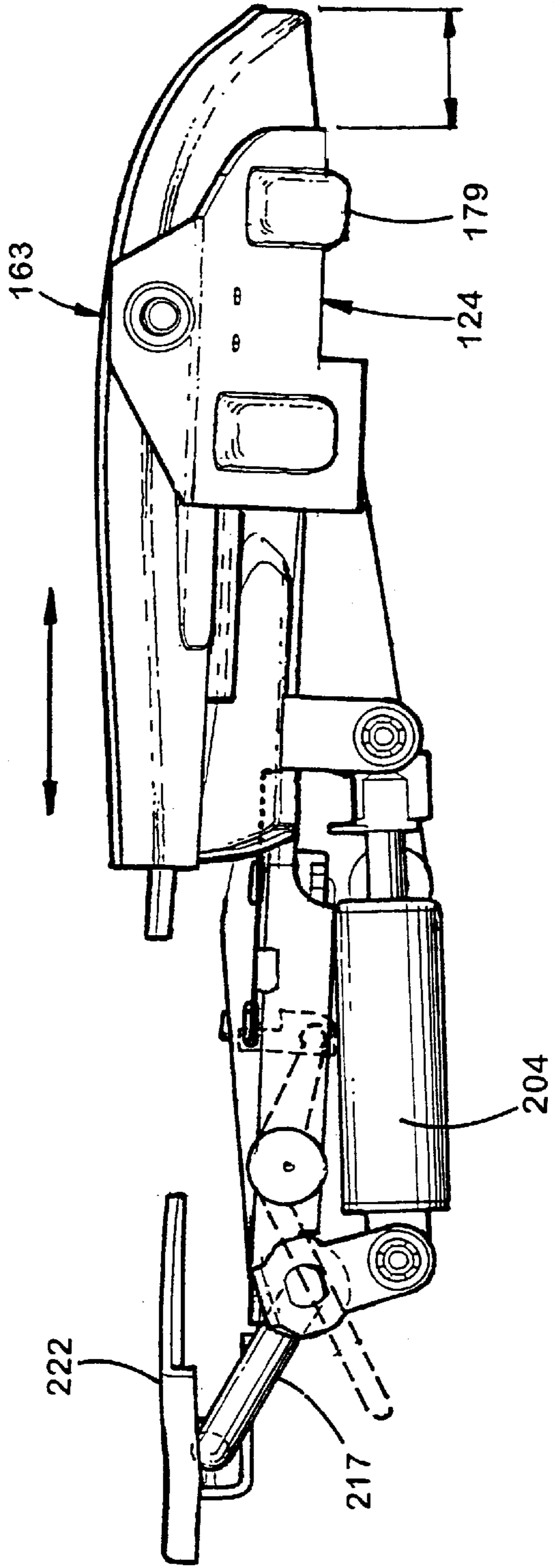


Fig. 25

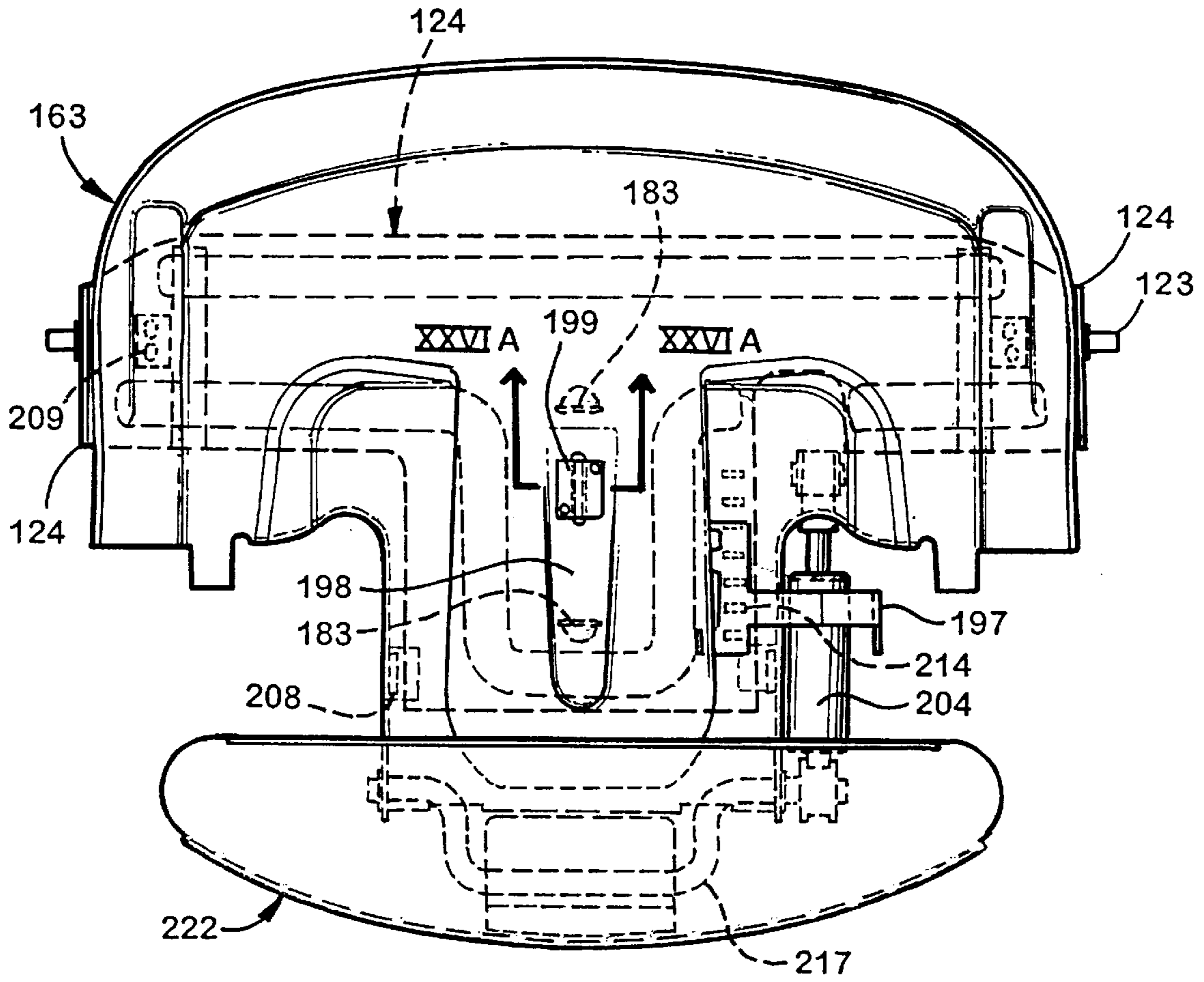


Fig. 26

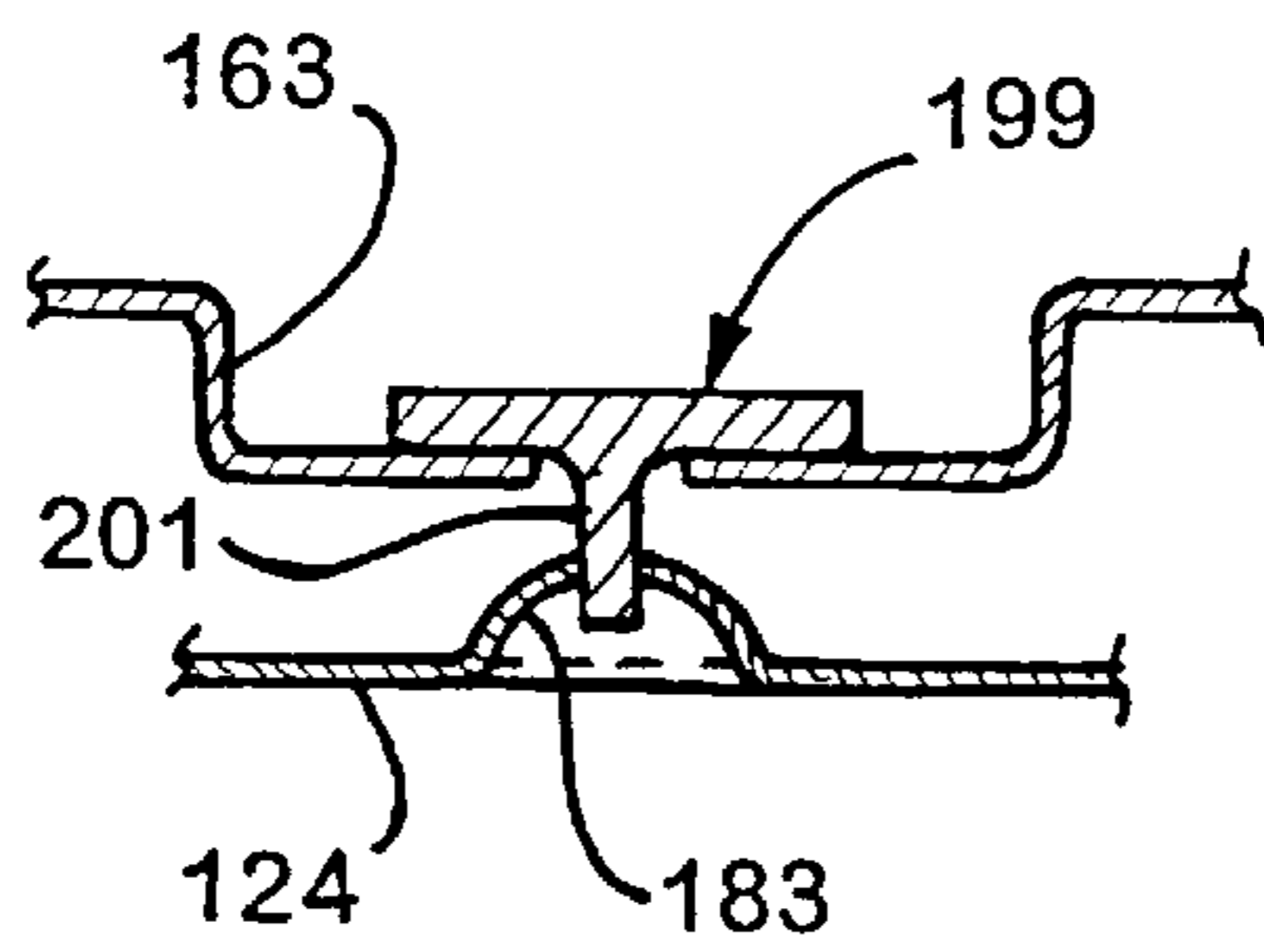


Fig. 26A

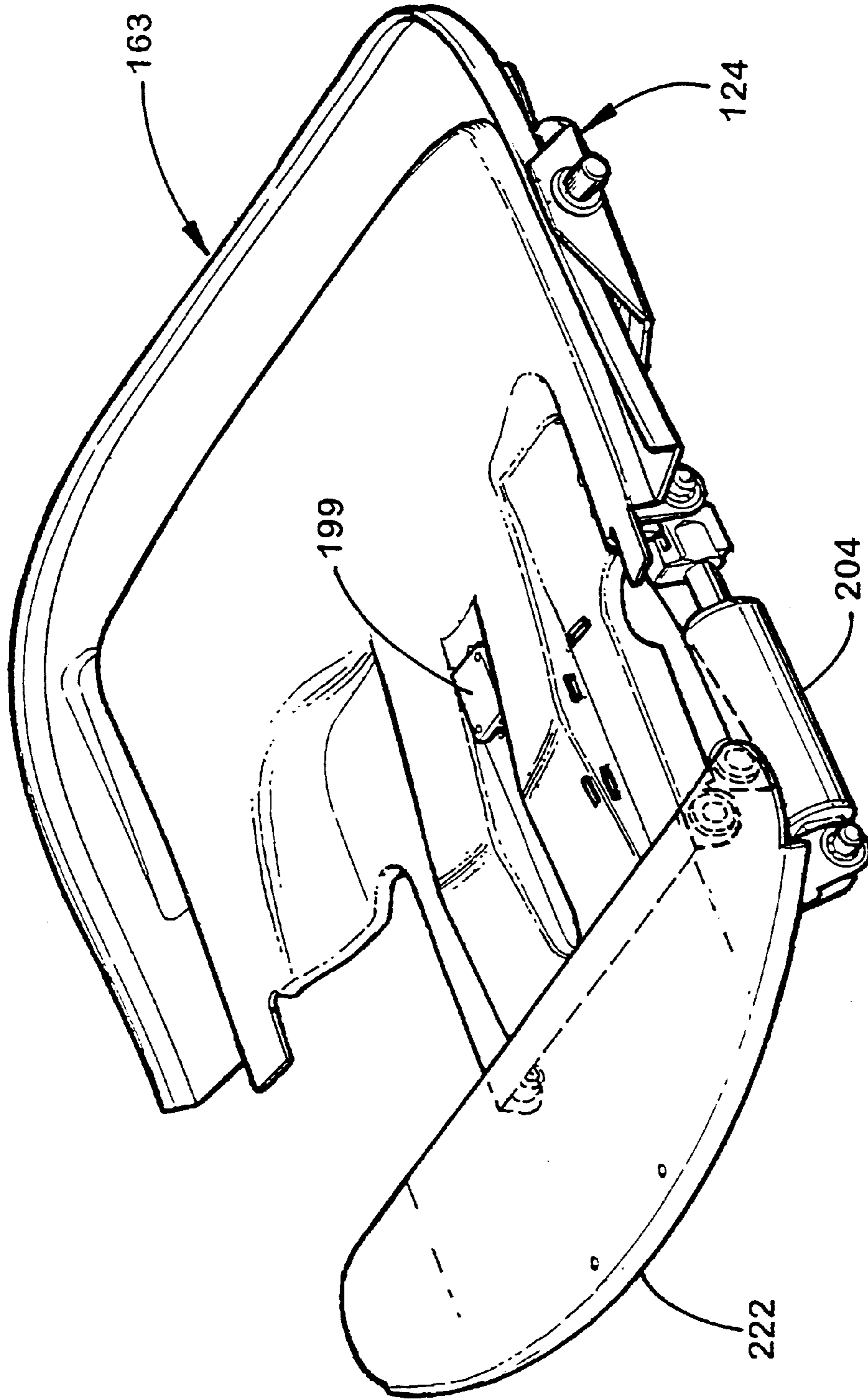


Fig. 27

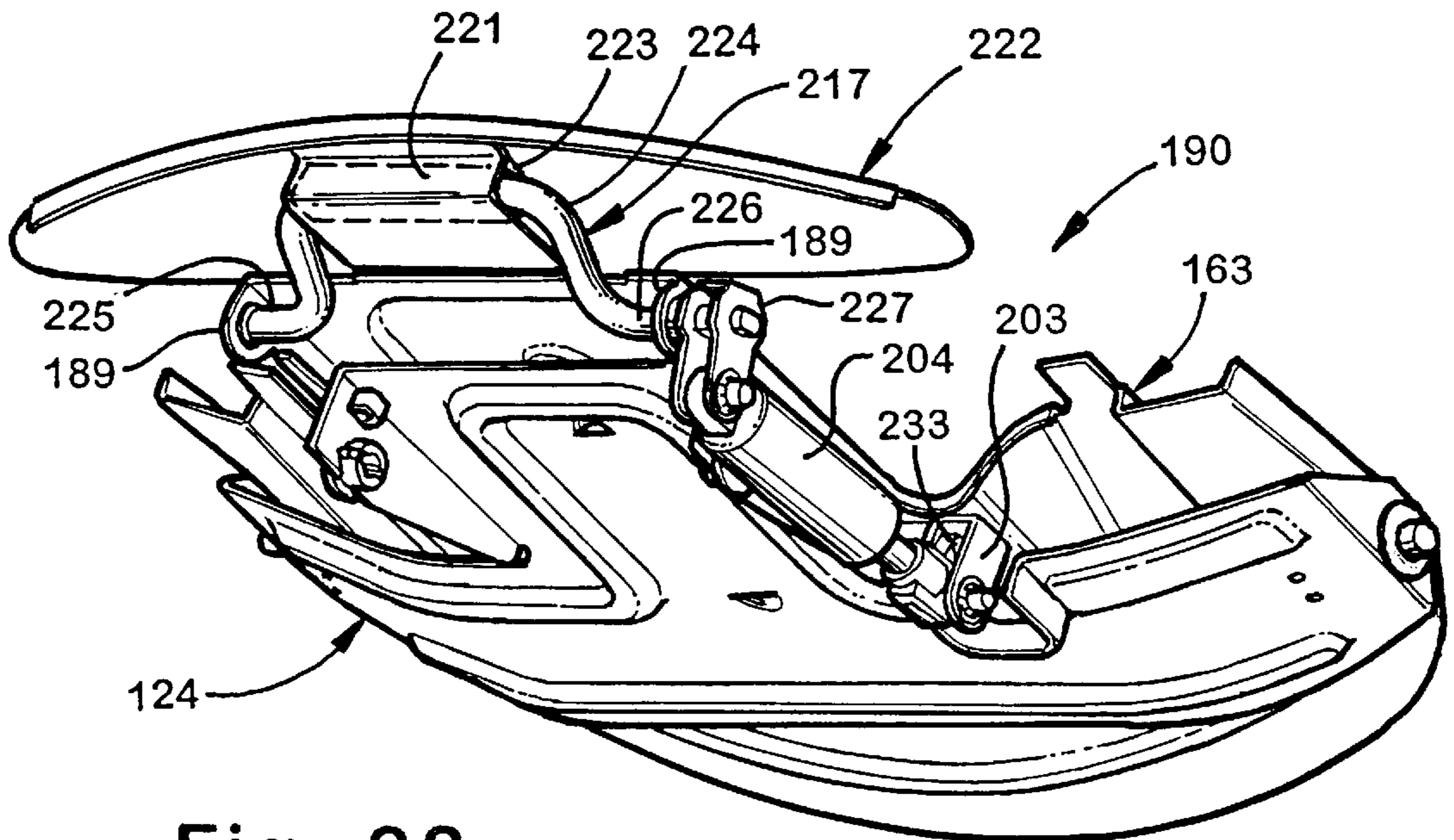


Fig. 28

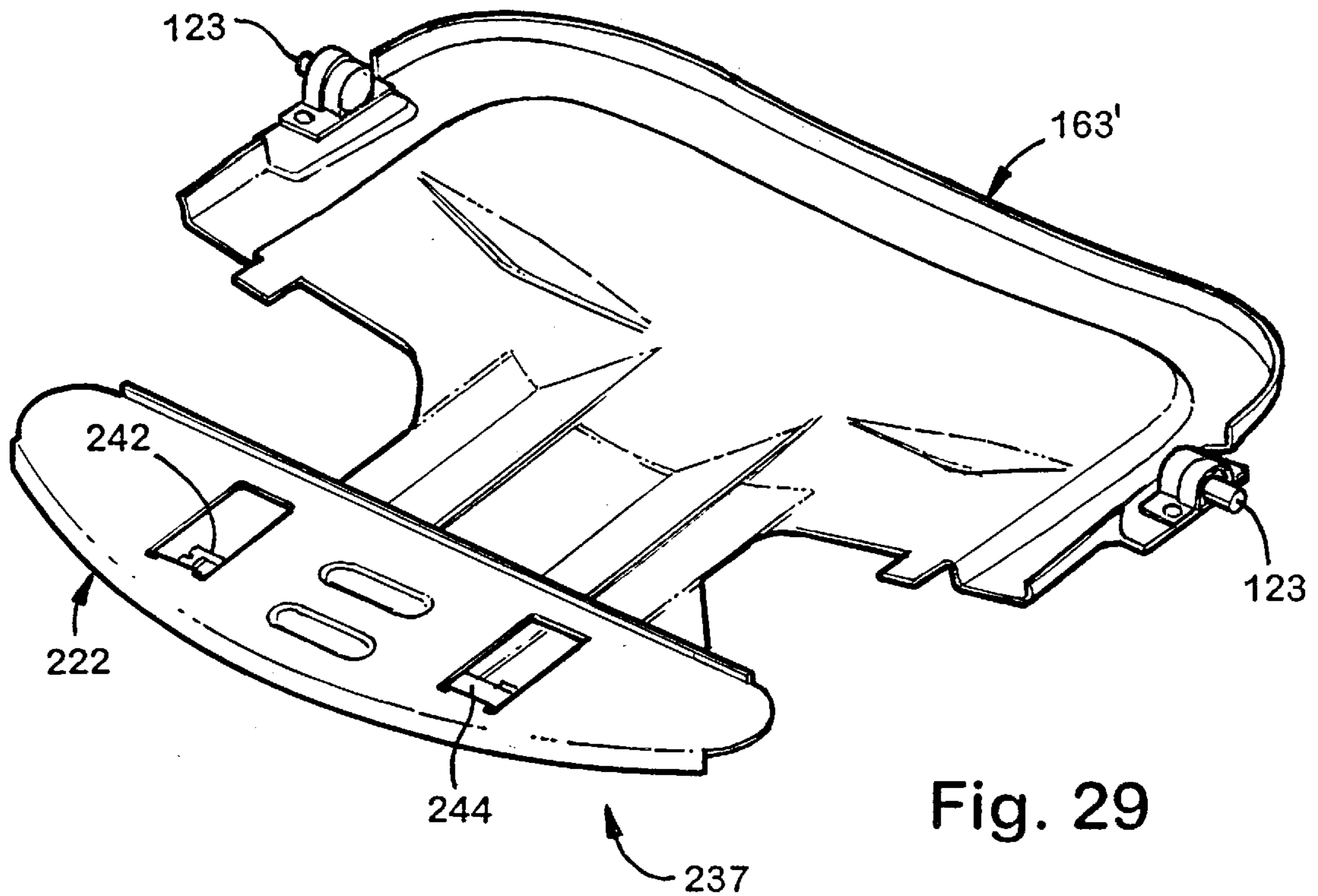
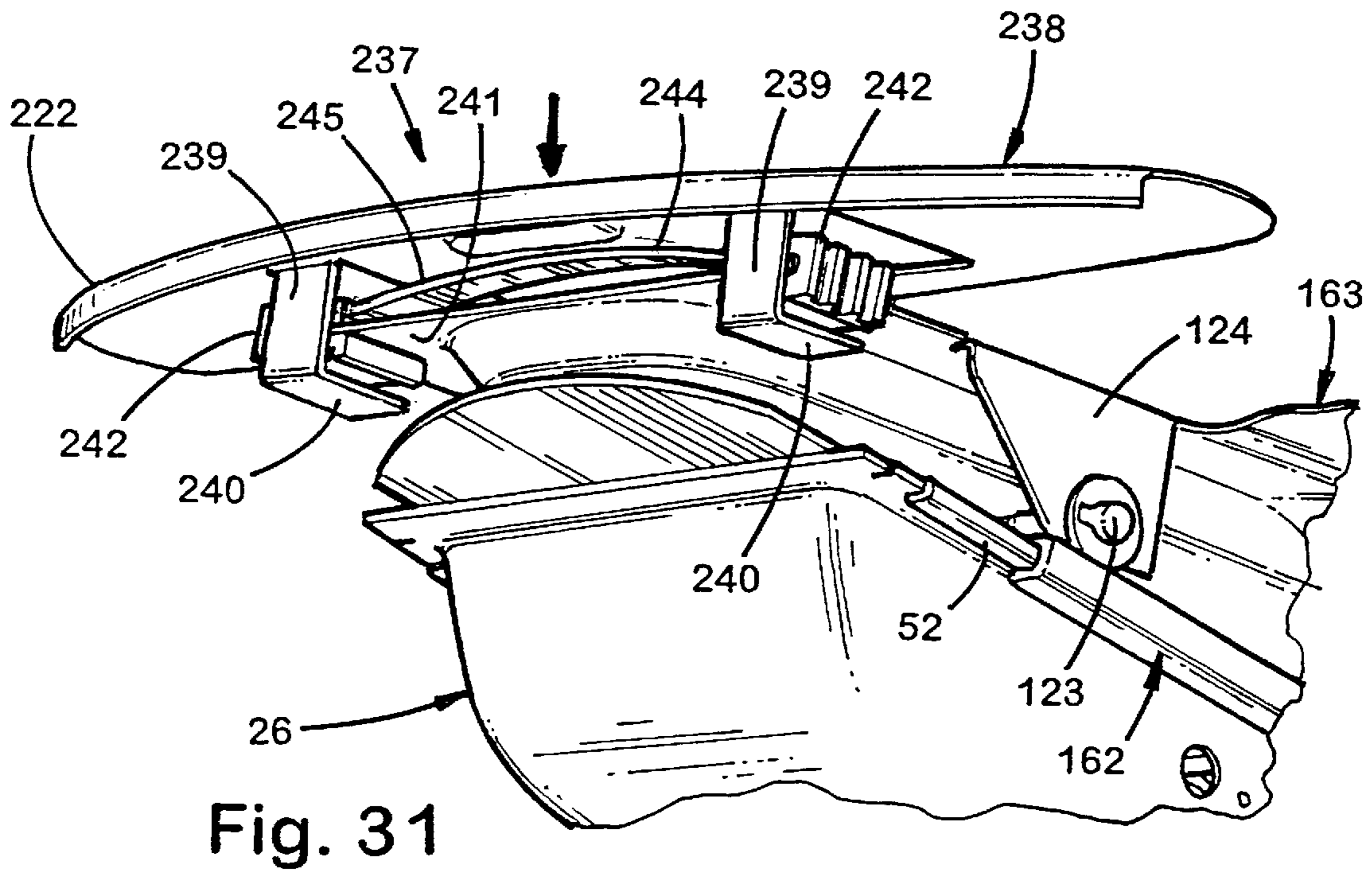
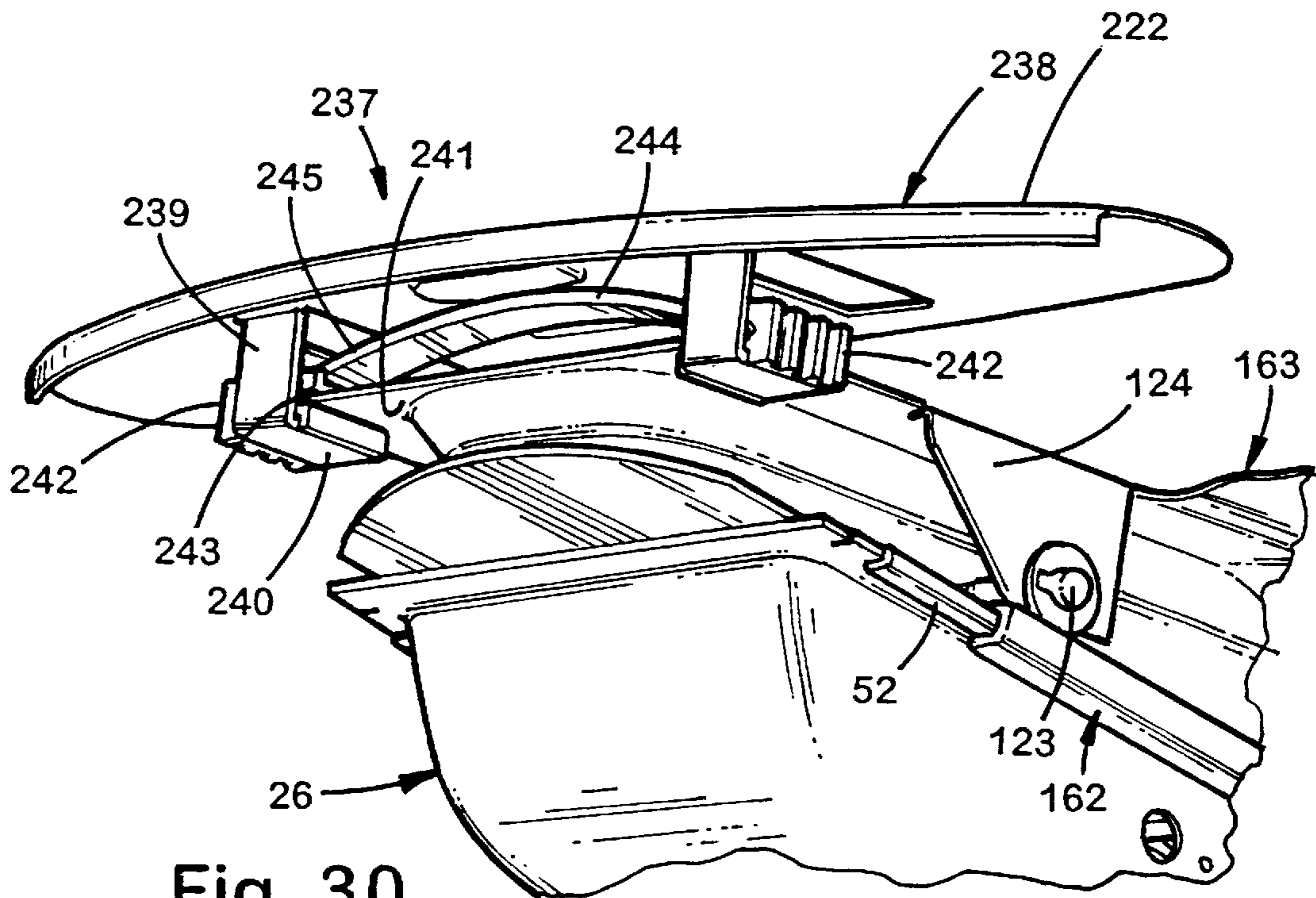


Fig. 29





## CHAIR WITH RECLINEABLE BACK AND ADJUSTABLE ENERGY MECHANISM

### RELATED APPLICATIONS

This application is related to the following co-assigned, copending applications, which are filed on even date herewith. The disclosure of each of these copending applications is incorporated herein by reference in its entirety:

Title	Application/U.S. Pat. No.
Chair Including Novel Back Construction	5,871,258
Chair with Novel Seat Construction	5,909,923
Chair with Novel Pivot Mounts and Method of Assembly	08/957,548
Synchrotilt Chair with Forwardly Movable Seat	08/957,604

### BACKGROUND

The present invention concerns chairs having a reclineable back and an adjustable energy mechanism for supporting the back during recline.

A synchrotilt chair is described in U.S. Pat. Nos. 5,050,931; 5,567,012; 4,744,603; and 4,776,633 (to Knoblock et al) having a base assembly with a control, a reclineable back pivoted to the control, and a seat operably mounted to the back and control for synchronous motion as the back is reclined. This prior art chair incorporates a semi-rigid flexible shell that, in combination with the chair support structure, provides a highly-controlled postural support during the body movements associated with tasks/work (e.g., when the back is in an upright position) and during the body movements associated with recline/relaxation (e.g., when the chair is in a reclined position). This prior art chair moves a seated user's upper body away from the user's work surface as the user reclines, thus providing the user with more area to stretch. However, we have discovered that often users want to remain close to their work surface and want to continue to work at the work surface, even while reclining and relaxing their body and while having continued postural support. In order to do this in the synchrotilt chair of U.S. Pat. No. 5,050,931, users must scoot their chair forwardly after they recline so that they can still easily reach their work surface. They must also push away when they move back to an upright position to avoid being pushed against their work surface. "Scooting" back and forth once or twice is perhaps not a serious problem, but often users, such as office workers using computers, are constantly moving between upright and reclined positions, such that the process of repeatedly scooting back and forth becomes annoying and disconcerting. In fact, moving around and not staying in a single static position is important to good back health in workers whose jobs require a lot of sitting.

Another disadvantage of moving a seated user's upper body significantly rearwardly upon recline is that the user's overall center of gravity moves rearward. By providing a more constant center of gravity, it is possible to design a reclineable chair having greater recline or height adjustment without sacrificing the overall stability of the chair. Also, reclineable chairs that move a seated user's upper body significantly rearwardly have a relatively large footprint, such that these chairs may bump into furniture or a wall when used in small offices or in a compact work area. Still another disadvantage is that large springs are required in

these existing reclineable chairs for back support, which springs are difficult to adjust due to the forces generated by the springs. However, the tension of these springs preferably should be adjustable so that heavier and lighter weight users can adjust the chair to provide a proper amount of support.

Concurrently, seated users want to be able to easily adjust the spring tension for providing support to the back during recline. Not only do heavier/larger people need greater/firmer back support than lighter/smaller people, but the amount of support required changes at a greater rate during recline. Specifically, lighter/smaller people need a lesser initial level of support as they begin to recline and need a moderately increased level of support as they continue to recline; while heavier/larger people need a significantly higher minimum initial level of support as they begin to recline and need a significantly increased level of support as they continue to recline. Restated, it is desirable to provide a chair that is easily adjustable in its initial level of support to the back during initial recline and that automatically also adjusts the rate of increase in support during recline. Further, it is desirable to provide a mechanism to allow such an easy adjustment (1) while seated; (2) by a relatively weaker person; (3) using easily manipulatable adjustment controls; and (4) while doing so with a control that is not easily damaged by a relatively strong person who may "overtorque" the control. Further, a compact spring arrangement is desired to provide optimal appearance and to minimize material cost and part size.

Manufacturers are becoming increasingly aware that adequate lumbar support is very important to prevent lower back discomfort and distress in workers who are seated for long periods. A problem is that the spinal shape and body shape of workers vary tremendously, such that it is not possible to satisfy all workers with the same shape. Further, the desired level of firmness or force of support in the lumbar area is different for each person and may vary as a seated user performs different tasks and/or reclines in the chair and/or becomes fatigued. In fact, a static lumbar support is undesirable. Instead, it is desirable to provide different lumbar shapes and levels of support over a work day. Accordingly, an adjustable lumbar system is desired that is constructed to vary the shape and force of lumbar support. At the same time, the adjustable lumbar system must be simple and easy to operate, easily reached while seated, mechanically non-complex and low cost, and aesthetically/visually pleasing. Preferably, adjustment of the shape and/or force in the lumbar area should not result in wrinkles in the fabric of the chair, nor unacceptable loose/saggy patches in the fabric.

Modern customers and chair purchasers demand a wide variety of chair options and features, and a number of options and features are often designed into chair seats. However, improvement in seats is desired so that a seated user's weight is adequately supported on the chair seat, but simultaneously so that the thigh area of a seated user is comfortably, adjustably supported in a manner that adequately allows for major differences in the shape and size of a seated user's buttocks and thighs. Additionally, it is important that such options and features be incorporated into the chair construction in a way that minimizes the number of parts and maximizes the use of common parts among different options, maximizes efficiencies of manufacturing and assembling, maximizes ease of adjustment and the logicalness of adjustment control positioning, and yet that results in a visually pleasing design.

Accordingly, a chair construction solving the aforementioned problems is desired.

## SUMMARY OF INVENTION

In one aspect of the present invention, a chair includes a base assembly with a control housing having opposing side flanges and a side pivot, a back pivoted to the base assembly for movement between upright and reclined positions, and a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back. An energy mechanism is provided for biasing the back toward the upright position. The energy mechanism includes an extendable/compressible spring positioned transversely in the control housing with one end supported on one of the side flanges, and further includes a lever pivoted to the side pivot and having a spring-engaging portion engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat. The side pivot, the spring-engaging portion, and the seat-biasing portion are spaced from each other and arranged so that the spring biases the lever about a fulcrum located generally at the side pivot to bias the back toward the upright position.

In another aspect of the present invention, a chair has a control housing including a pivot member, a reclineable back operably connected to the control housing for movement between upright and reclined positions, and an energy source in the control housing. The chair also includes an improved adjustable back tension controller for the chair wherein the pivot member is adjustable, and a lever engages the energy source and the pivot member and is operably connected to the back for biasing the back to the upright position. The lever and the pivot member have non-slip interfacing surfaces, at least one of which is curvilinear, so that the interfacing surfaces engage to define a fulcrum as the lever is rotated during recline of the back, and further so that the fulcrum changes location as the pivot member is adjusted to change a moment arm over which the energy source operates.

In yet another aspect of the present invention, a chair includes a base assembly, a component comprising one of a reclineable back and a movable seat pivoted to the base assembly for movement between first and second positions, and a spring with one end supported on the base assembly and another end operably connected to the component. The spring has a length and, when the component is moved from the first position to the second position, is simultaneously longitudinally compressed along the length and also laterally bent in a direction transverse to the length.

In yet another aspect of the present invention, a chair includes a base assembly including a control housing, a seat slidingly supported on the control housing, a back frame pivoted to the base assembly for movement between upright and reclined positions and operably attached to the seat, so that pivotal movement of the back frame and sliding movement of the seat are synchronized, and an energy mechanism including a spring having a length and an L-shaped torque member with a first leg engaging an end of the coil spring, and a second leg extending generally parallel the length of the spring. The first leg pivotally engages the control housing at a location spaced from the end of the spring. The second leg is operably connected to one of the seat and the back frame so that the spring biases the torque member in a manner biasing the back frame toward the upright position.

In yet another aspect of the present invention, a chair includes a base assembly including a control housing, a seat slidingly supported on the control housing, a back assembly pivoted to the base frame for movement between upright and reclined positions and operably attached to the seat, so that pivotal movement of the back frame and sliding movement

of the seat are synchronized. The control housing defines a relatively-thin horizontally-extending compartment under the seat. An adjustable energy mechanism is operably positioned in the compartment. The adjustable energy mechanism includes an extensible energy source, a lever operably connected between the energy source and the seat, and an adjustment member adjustably pivotally supporting the lever for adjustably controlling force transmitted from the energy source through the lever to the seat. The energy source, the lever, and the adjustment member are movable in horizontal directions only so as to operate within the relatively-thin horizontally-extending compartment.

In yet another aspect of the present invention, a chair control includes a control housing, a component operably attached to the control housing for movement between a plurality of positions, an actuator on the control housing operably connected to the component for controlling movement of the component, a manually-operable handle for operating the actuator, and an overtorque device connecting the handle to the actuator. The overtorque device is constructed to limit force transmitted from the handle to the actuator to a maximum amount to prevent damage to the chair control.

In yet another aspect of the present invention, a control includes a control housing, a single stored energy source positioned in the control housing providing a compressive force, and a lever operably interconnected with said single energy source for movement between upright and reclined positions. The single stored energy source both exerts pretension to bias the lever toward the upright position and provides resistance to tilting of the lever when reclining. The control further includes a controller for regulating the pretension of the stored energy source and tilt rate of the lever, with the controller being configured for adjustment without an operator having to overcome a compressive force of the said single stored energy source.

In yet another aspect of the present invention, a chair includes a base assembly including a control housing, a single stored energy source positioned in the control housing providing a compressive force, and a back support operably interconnected with said single energy source for movement between upright and reclined positions. The single stored energy source both exerts pretension to bias the back support toward the upright position and provides resistance to tilting of the back support when reclining. The control further includes a controller for regulating the pretension of the stored energy source and tilt rate of the back support, the controller including a lever defining an adjustable fulcrum point that can be adjusted without overcoming the compressive force of the said single stored energy source.

In yet another aspect of the present invention, a control includes a control housing, a stored energy source positioned in the control housing, and a back-supporting first lever operably interconnected with said energy source for movement between upright and reclined positions. The stored energy source both exerts pretension to bias the first lever toward the upright position and provides resistance to tilting of the first lever when reclining. The control further includes a controller for regulating the pretension of the stored energy source of the first lever. The controller includes a crank lever within the control housing. The crank lever has one end engaging the stored energy source and the other end operably interconnected with the first lever. The crank lever has portions between the two ends forming a fulcrum, so that the energy source biases the crank lever about the fulcrum to bias the first lever toward the upright position.

In yet another aspect of the present invention, a control includes a control housing, a stored energy source positioned

in the control housing, and a first lever operably interconnected with said energy source for movement between upright and reclined positions. The stored energy source both exerts pretension to bias the first lever toward the upright position and provides resistance to tilting of the first lever when reclining. The control further includes an adjustable controller for adjustably regulating the pretension of the stored energy source. The controller includes a manually-operable handle for regulating the pretension of the stored energy source, and an overtorque device configured to limit the physical force transmitted from the handle to the controller.

These and other features and advantages of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

#### DETAILED DESCRIPTION OF FIGURES

FIGS. 1–3 are front, rear, and side perspective views of a reclineable chair embodying the present invention;

FIGS. 4A and 4B are exploded perspective views of upper and lower portions of the chair shown in FIG. 1;

FIGS. 5 and 6 are side views of the chair shown in FIG. 1, FIG. 5 showing the flexibility and adjustability of the chair when in the upright position and FIG. 6 showing the movements of the back and seat during recline;

FIG. 7 is a front view of the chair shown in FIG. 1 with an underseat aesthetic cover removed;

FIG. 8 is a top view of the control including the primary energy mechanism, the moment arm shift adjustment mechanism, and the back-stop mechanism, the primary energy mechanism being adjusted to a relatively low torque position and being oriented as it would be when the back is in the upright position so that the seat is in its rearward at-rest position, the back-stop mechanism being in an intermediate position for limiting the back to allow a maximum recline;

FIG. 8A is a perspective view of the base frame and the chair control shown in FIG. 8, some of the seat and back support structure being shown in phantom lines and some of the controls on the control being shown in solid lines to show relative locations thereof;

FIG. 9 is a perspective view of the control and primary energy mechanism shown in FIG. 8, the primary energy mechanism being adjusted to a low torque position and shown as if the back is in an upright position such that the seat is moved rearwardly;

FIG. 9A is a perspective view of the control and primary energy mechanism shown in FIG. 9, the primary energy mechanism being adjusted to the low torque position but shown as if the back is in a reclined position such that the seat is moved forwardly and the spring is compressed;

FIG. 9B is a perspective view of the control and primary energy mechanism shown in FIG. 9, the primary energy mechanism being adjusted to a high torque position and shown as if the back is in an upright position such that the seat is moved rearwardly;

FIG. 9C is a perspective view of the control and primary energy mechanism shown in FIG. 9, the primary energy mechanism being adjusted to the high torque position but shown as if the back is in a reclined position such that the seat is moved forwardly and the spring is compressed;

FIG. 9D is a graph showing torsional force versus angular deflection curves for the primary energy mechanism of FIGS. 9–9C, the curves including a top curve showing the

forces resulting from the high torque (long moment arm engagement of the main spring) and a bottom curve showing the forces resulting from the low torque (short moment arm engagement of the main spring);

FIG. 10 is an enlarged top view of the control and primary energy mechanism shown in FIG. 8, including controls for operating the back-stop mechanism, the back-stop mechanism being shown in an off position;

FIG. 11 is an exploded view of the mechanism for adjusting the primary energy mechanism, including the overtorque release mechanism for same;

FIG. 11A is a plan view of a modified back-stop control and related linkages; FIG. 11B is an enlarged fragmentary view, partially in cross section, of the circled area in FIG. 11A; and FIG. 11C is a cross-sectional view taken along the line XIC—XIC in FIG. 11A;

FIG. 12 is a side view of the back assembly shown in FIG. 1 including the back frame and the flexible back shell and including the skeleton and flesh of a seated user, the back shell being shown with a forwardly-convex shape in solid lines and being shown in different flexed shapes in dashed and dotted lines;

FIG. 12A is an enlarged perspective view of the back frame shown in FIG. 4A, the back frame being shown as if the molded polymeric outer shell is transparent so that the reinforcement can be easily seen;

FIGS. 12B and 12C are cross sections taken along lines XXIIIB—XXIIIB and XXIIC—XXIIC in FIG. 12A;

FIGS. 12D–12I are views showing additional embodiments of flexible back shell constructions adapted to move sympathetically with a seated user's back;

FIG. 12J is an exploded perspective view of the torsionally-adjustable lumbar support spring mechanism shown in FIG. 4A, and FIG. 12JJ is an exploded view of the hub and spring connection of FIG. 12J taken from an opposite side of the hub;

FIG. 12K is an exploded perspective view of a modified torsionally-adjustable lumbar support spring mechanism;

FIGS. 12L and 12LL are side views of the mechanism shown in FIG. 12K adjusted to a low torque position, and FIGS. 12M and 12MM are side views of the mechanism adjusted to a high torque position, FIGS. 12L and 12M highlighting the spring driver, and FIGS. 12LL and 12MM highlighting the lever;

FIG. 12N is a fragmentary cross-sectional side view of the back construction shown in FIG. 12;

FIG. 13 is a cross-sectional side view taken along lines XIII—XIII showing the pivots that interconnect the base frame to the back frame and that interconnect the back frame to the seat frame;

FIG. 13A is a cross-sectional side view of modified pivots similar to FIG. 13, but showing an alternative construction;

FIGS. 14A and 14B are perspective and front views of the top connector connecting the back shell to the back frame;

FIG. 15 is a rear view of the back shell shown in FIG. 4A;

FIG. 16 is a perspective view of the back including the vertically-adjustable lumbar support mechanism shown in FIG. 4A;

FIGS. 17 and 18 are front and top views of the vertically-adjustable lumbar support mechanism shown in FIG. 16;

FIG. 19 is a front view of the slide frame of the vertically-adjustable lumbar support mechanism shown in FIG. 18;

FIG. 20 is a top view, partially in cross section, of the laterally-extending handle of the vertically-adjustable lum-

bar support mechanism shown in FIG. 17 and its attachment to the slide member of the lumbar support mechanism;

FIG. 21 is a perspective view of the depth-adjustable seat shown in FIG. 4B including the seat carrier and the seat undercarriage/support frame slidably mounted on the seat carrier, the seat undercarriage/support frame being partially broken away to show the bearings on the seat carrier, the seat cushion being removed to reveal the parts therebelow;

FIG. 22 is a top view of the seat carrier shown in FIG. 21, the seat undercarriage/rear frame being removed but the seat frame slide bearings being shown and the seat carrier depth-adjuster stop device being shown;

FIG. 23 is a top perspective view of the seat undercarriage/rear frame and the seat carrier shown in FIG. 21 including a depth-adjuster control handle, a linkage, and a latch for holding a selected depth position of the seat;

FIGS. 24 and 25 are side views of the depth-adjustable seat shown in FIG. 21, FIG. 24 showing the seat adjusted to maximize seat depth, and FIG. 25 showing the seat adjusted to minimize seat depth; FIGS. 24 and 25 also showing a manually-adjustable “active” thigh support system including a gas spring for adjusting a front portion of the seat shell to provide optimal thigh support;

FIG. 26 is a top view of the seat support structure shown in FIGS. 24 and 25 including the seat-carrier (shown mostly in dashed lines), the seat undercarriage/rear frame, the active thigh support system with gas spring and reinforcement plate for adjustably supporting the front portion of the seat, and portions of the depth-adjustment mechanism including a stop for limiting the maximum forward and rearward depth adjustment of the seat and the depth-setting latch;

FIG. 26A is a cross section taken along line XXVIA—XXVIA in FIG. 26 showing the stop for the depth-adjuster mechanism;

FIGS. 27 and 28 are top and bottom perspective views of the seat support structure shown in FIG. 26;

FIGS. 29 and 30 are top and bottom perspective views of a seat similar to that shown in FIG. 26, but where the manually-adjustable thigh support system is replaced with a passive thigh support system including a leaf spring for supporting a front portion of the seat; and

FIG. 31 is a bottom perspective view of the brackets and guide for supporting ends of the leaf spring as shown in FIG. 30, but with the thigh-supporting front portion of the seat flexed downwardly causing the leaf spring to flex toward a flat compressed condition.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

For purposes of description herein, the terms “upper,” “lower,” “right,” “left,” “rear,” “front,” “vertical,” “horizontal,” and derivatives thereof shall relate to the invention as oriented in FIG. 1 with a person seated in the chair. However, it is to be understood that the invention may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as unnecessarily limiting, unless the claims expressly state otherwise.

A chair construction 20 (FIGS. 1 and 2) embodying the present invention includes a castored base assembly 21 and

a reclineable back assembly 22 pivoted to the base 21 for movement about a stationary back-tilt axis 23 between upright and reclined positions. A seat assembly 24 (FIG. 6) is pivoted at its rear to the back 22 for movement about a seat-tilt axis 25. Seat-tilt axis 25 is offset rearwardly and downwardly from the back-tilt axis 23, and the seat 24 is slidably supported at its front on the base 21 by linear bearings, such that the seat 24 slides forwardly and its rear rotates downwardly and forwardly with a synchrotilt movement as the back 22 is reclined (see FIG. 6). The synchronous motion initially moves the back to seat at an angular synchronous ratio of about 2.5:1, and when near the fully reclined position moves the back to seat at an angular synchronous ratio of about 5:1. The seat 24 and back 22 movement during recline provides an exceptionally comfortable ride that makes the seated user feel very stable and secure. This is due in part to the fact that the movement keeps the seated user’s center of gravity relatively constant and keeps the seated user in a relatively balanced position over the chair base. Also, the forward slide/synchronous motion keeps the seated user near his/her work during recline more than in previous synchrotilt chair constructions, such that the problem of constantly scooting forward after reclining and then scooting rearward when moving toward an upright position is greatly reduced, if not eliminated. Another advantage is that the chair construction 20 can be used close to a wall behind the chair or in a small office, with less problems resulting from interface from office furnishings during recline. Still further, we have found that the spring 28 for biasing the back 22 toward an upright position can be potentially reduced in size because of the reduced rearward shifting of a seated user’s weight in the present chair.

The base 21 includes a control housing 26. A primary energy mechanism 27 (FIG. 8) is operably positioned in control housing 26 for biasing the seat 24 rearwardly. Due to the interconnection of the back 22 and the seat 24, the rearward bias of the seat 24 in turn biases the back 22 toward an upright position. Primary energy mechanism 27 (FIG. 8) includes a main spring 28 positioned transversely in the control housing 26 that operably engages a torque member or lever 54. The tension and torque provided by the main spring 28 is adjustable via an adjustable moment arm shift (MAS) system 29 also positioned substantially in the control housing 26. A visual cover 26' (FIG. 1) covers the area between the control housing 26 and the underside of the seat 24. The back assembly 22 includes a back support or back frame 30 (FIG. 4A) with structure that defines pivots/axes 23 and 25. A flexible/compliant back shell construction 31 is pivoted to back frame 30 at top connections 32 and bottom connections 33 in a manner providing an exceptionally comfortable and sympathetic back support. A torsionally-adjustable lumbar support spring mechanism 34 is provided to bias the back shell 31 forwardly into a forwardly-convex curvilinear shape optimally suited for providing good lumbar pressure. A vertically-adjustable lumbar support 35 (FIG. 16) is operatively mounted on back shell 31 for vertical movement to provide an optimal shape and pressure location to the front support surface on back 22. The seat 24 is provided with various options to provide enhanced chair functions, such as a back-stop mechanism 36 (FIG. 8) which adjustably engages the seat 24 to limit recline of the back 22. Also, the seat 24 can include active and passive thigh support options (see FIGS. 24 and 30, respectively), seat depth adjustment (see FIGS. 28 and 25), and other seat options, as described below.

### Base Assembly

The base assembly 21 (FIG. 1) includes a floor-engaging support 39 having a center hub 40 and radially-extending castored legs 41 attached to the center hub 40 in a spider-like configuration. A telescopingly-extendable center post 42 is positioned in center hub 40 and includes a gas spring that is operable to telescopingly extend the post 42 to raise the height of the chair. The control housing 26 of base assembly 21 is pan shaped (FIG. 11) and includes bottom panels and flanged sidewalls forming an upwardly-open structural member. A notch 43 is formed in one sidewall of the housing 26 for receiving a portion of the adjustable control for the MAS system 29. A front of the housing 26 is formed into an upwardly-facing U-shaped transverse flange 44 for receiving a transverse structural tube 45 (FIG. 8A), and a hole 46 (FIG. 11) is formed generally adjacent flange 44. The transverse tube 45 is welded to the flange 44 and extends substantially horizontally. A reinforcement channel 47 is welded in housing 26 immediately in front of transverse structural tube 45. A frustoconical tube section 48 is welded vertically to reinforcement 47 above hole 46, which tube section 48 is shaped to mateably and securely engage the upper end of extendable center post 42. A pair of stiff upwardly-extending side arms 49 (sometimes also called “struts” or “pods”) are welded to the opposing ends of transverse tube 45. The side arms 49 each include a stiff plate 50 on their inside surface. The plates 50 include weld nuts 51 that align to define the back-tilt axis 23. The housing 26, transverse tube 45, and side arms 49 form a base frame that is rigid and sturdy. The sidewalls of the housing 26 include a lip or flange that extends along their upper edge to reinforce the sidewalls. A cap 52 is attached to the lips to form a stationary part of a linear bearing for slidably supporting a front of the seat.

### Primary Energy Mechanism and Operation

It is noted that the housing 26 shown in FIGS. 9–9C and 10 is slightly longer and with different proportions than the housing of FIGS. 8, 8A, and 11, but the principles of operation are the same. The primary energy mechanism 27 (FIG. 8) is positioned in housing 26. The primary energy mechanism 27 includes the spring 28, which is operably connected to the seat 24 by an L-shaped torque member or bell crank 54, a link 55, and a seat-attached bracket 56. The spring 28 is a coil spring transversely positioned in housing 26, with one end supported against a side of housing 26 by a disc-shaped anchor 57. The anchor 57 includes a washer to support the end of the spring 28 to prevent noise, and further includes a protrusion that extends into a center of the end of the spring 28 to securely grip the spring 28, but that allows the spring 28 to be compressed and to tilt/flex toward a side while the torque member or bell crank 54 is being pivoted. The L-shaped torque member or bell crank 54 includes a short leg or lever 58 and a long leg 59. The short leg 58 has a free end that engages an end of the spring 28 generally proximate a left side of housing 26 with a washer and protrusion similar to anchor 57. Short leg 58 is arcuately shaped and includes an outer surface facing the adjacent sidewall of housing 26 that defines a series of teeth 60. Steel strips 61 are attached to the top and bottom sides of the short leg 58 and have an outer arcuate surface that provides a smooth rolling bearing surface on the leg 58, as described below. The arcuate surface of the strips 61 is generally located at about the apex or the pitch diameter of the gear teeth 60. The short leg 58 extends generally perpendicular to a longitudinal direction of spring 28 and the long leg 59 extends generally parallel the length of spring 28, but is spaced from the spring 28. Link 55 (FIG. 8) is pivoted to an end of long leg 59 and is also pivoted to the seat-attached bracket 56.

A crescent-shaped pivot member 63 (FIG. 11) includes an arcuate roller bearing surface that rollingly engages the curved surface of steel strips 61 on short leg 58 to define a moving fulcrum point. Pivot member 63 also includes a rack of teeth 64 configured to mateably engage the teeth 60 on short leg 58 to prevent any slippage between the interfacing roller bearing surfaces of leg 58 and pivot member 63. Pivot member 63 is attached to a side of the housing 26 at the notch 43. When the seat 24 is in a rearward position (i.e., the back is in an upright position) (FIG. 9), the long leg 59 is located generally parallel and close to the spring 28 and the short leg 58 is pivoted so that the spring 28 has a relatively low amount of compression. In this position, the compression of spring 28 is sufficient to adequately bias the seat 24 rearwardly and in turn bias the back frame 30 to an upright position for optimal yet comfortable support to a seated user. As a seated user reclines, the seat 24 is moved forwardly (FIG. 9A). This causes the L-shaped torque member or bell crank 54 to roll on pivot member 63 at the fulcrum point in a manner compressing spring 28. As a result, spring 28 provides increasing force resisting the recline, which increasing force is needed to adequately support a person as they recline. Notably, the short leg 58 “walks” along the crescent-shaped pivot member 63 a short distance during recline, such that the actual pivot location changes slightly during recline. The generous curvilinear shapes of the short leg 58 and the pivot member 63 prevent any abrupt change in the support to the back during recline, but it is noted that the curvilinear shapes of these two components affect the spring compression in two ways. The “walking” of the short leg 58 on the pivot member 63 affects the length of the moment arm to the actual pivot point (i.e., the location where the teeth 60 and 64 actually engage at any specific point in time). Also, the “walking” can cause the spring 28 to be longitudinally compressed as the “walking” occurs. However, in a preferred form, we have designed the system so that the spring 28 is not substantially compressed during adjustment of the pivot member 63, for the reason that we want the adjustment to be easily accomplished. If adjustment caused the spring 28 to be compressed, the adjustment would require extra effort to perform the adjustment, which we do not prefer in this chair design.

As discussed below, the pivot member 63 is adjustable to change the torque arm over which the spring 28 operates. FIG. 9B shows the primary energy mechanism 27 adjusted to a high torque position with the seat 24 being in a rearward position (and the back frame 30 being in an upright position). FIG. 9C shows the primary energy mechanism 27 still adjusted to the high torque condition, but in the compressed condition with the seat 24 in a forward position (and the back frame 30 being in an upright position). Notably, in FIGS. 9B and 9C, the pivot member 63 has been adjusted to provide a longer torque arm on lever 58 over which the spring 28 acts.

FIG. 9D is a graph illustrating the back torque generated by spring 28 as a function of the angle of recline. As apparent from the graph, the initial force of support can be varied by adjustment (as described below). Further, the rate of change of torsional force (i.e., the slope) varies automatically as the initial torsional force is adjusted to a higher force, such that a lower initial spring force results in a flatter slope, while a higher initial spring force results in a steeper slope. This is advantageous since lighter/smaller people not only require less support in the upright position of the chair, but also require less support during recline. Contrastingly, heavier/larger people require greater support when in upright and reclined positions. Notably, the desired slope of

the high and low torque force/displacement curves can be designed into the chair by varying the shape of the short leg **58** and the pivot member **63**.

The crescent-shaped pivot member **63** (FIG. **11**) is pivotally supported on housing **26** by a bracket **65**. The bracket **65** includes a tube section **66** and a configured end **67** with a juncture therebetween configured to mateably engage the notch **43** in the side of housing **26**. The configured end **67** includes a pair of flanges **68** with apertures defining an axis of rotation **69** for the pivot member **63**. The pivot member **63** is pivoted to the flanges **68** by a pivot pin and is rotatable around the axis **69**. By rotating the pivot member **63**, the engagement of teeth **60** and **64** and the related interfacing surfaces change in a manner causing the actual pivot point along short leg **58** of L-shaped torque member or bell crank **54** to change. (Compare FIGS. **9** and **9B**.) As a result, the distance from the end of spring **28** to the actual pivot point changes. This results in a shortening (or lengthening) in the torque arm over which the spring **28** operates, which in turn results in a substantial change in the force/displacement curve (compare the top and bottom curves in FIG. **9D**). The change in moment arm is relatively easily accomplished because the spring **28** is not compressed substantially during adjustment, since the interfacing surface on pivot member **63** defines a constant radius around its axis of rotation. Thus, adjustment is not adversely affected by the strength of spring **28**. Nonetheless, the adjustment greatly affects the spring curve because of the resulting change in the length of the moment arm over which the spring **28** operates.

Pivoting of the pivot member **63** is accomplished through use of a pair of apertured flanges **70** (FIG. **11**) on the pivot member **63** that are spaced from axis **69**. An adjustment rod **71** extends through tube section **66** into configured end **67** and is pivoted to the apertured flanges **70**. Rod **71** includes a threaded opposite end **72**. An elongated nut **73** is threaded onto rod end **72**. Nut **73** includes a washer **73'** that rotatably engages an end of the tube section **66**, and further includes a configured end **74** having longitudinally-extending ribs or slots shaped to mateably telescopingly engage mating ribs **75** on a driving ring **76**. A handle **77** is rotatably mounted on tube section **66** and is operably connected to the driving ring **76** by an overtorque clutch ring **78**. Clutch ring **78** includes resilient fingers **79** that operably engage a ring of friction teeth **80** on the driving ring **76**. Fingers **79** are shaped to frictionally slip over teeth **80** at a predetermined torsional load to prevent damage to components of the chair **20**. A retainer **81** includes resilient legs **81'** that snappingly engage the end **74** of the nut **73** to retain the driving ring **76** and the clutch ring **78** together with a predetermined amount of force. A spacer/washer **82** rides on the end of the nut **73** to provide a bearing surface to better support the clutch ring **78** for rotation. An end cap **83** visually covers an end of the assembly. The end cap **83** includes a center protrusion **84** that snaps into the retainer **81** to forcibly keep the resilient legs of the retainer **81** engaged in the end of the nut **73**.

In use, adjustment is accomplished by rotating the handle **77** on tube section **66**, which causes nut **73** to rotate by means of clutch ring **78** and driving ring **76** (unless the force required for rotation of the nut **73** is so great that the clutch ring **78** slips on driving ring **76** to prevent damage to the components). As the nut **73** rotates, the rod **71** is drawn outwardly (or pressed inwardly) from the housing **26**, causing the pivot member **63** to rotate. Pivoting the pivot member **63** changes the point of engagement (i.e. fulcrum point) of the pivot member **63** and the short leg **58** of the L-shaped torque member or bell crank **54**, thus changing the moment arm over which the spring **28** acts.

### Back-Stop Mechanism

The back-stop mechanism **36** (FIG. **8**) includes a cam **86** pivoted to the housing **26** at location **87**. The cam **86** includes stop surfaces or steps **88**, detent depressions **89** that correspond to surfaces **88**, and teeth **90**. The steps **88** are shaped to mateably engage the seat-attached bracket **56** to limit the rearward rotation of the back frame **30** by limiting the rearward movement of the seat **24**. This allows a seated user to limit the amount of recline to a desired maximum point. A leaf spring **91** (FIG. **10**) is attached to the housing **26** by use of a U-shaped finger **92** that slips through a first hole and hooks into a second hole in the housing **26**. The opposite end of the leaf spring includes a U-shaped bend **93** shaped to mateably slidably engage the detent depressions **89**. The depressions **89** correspond to the steps **88** so that, when a particular step **88** is selected, a corresponding depression **89** is engaged by spring **91** to hold the cam **86** in the selected angular position. Notably, the steps **88** (and the depressions **89**) are located angularly close together in the area corresponding to chair positions close to the upright position of the back frame **30**, and are located angularly farther apart in the area corresponding to more fully reclined chair positions. This is done so that seated users can select from a greater number of back-stopping positions when near an upright position. It is noted that seated users are likely to want multiple back-stopping positions that are close together when near an upright position, and are less likely to select a back-stopping position that is near the fully reclined chair position.

The cam **86** is rotated through use of a control that includes a pivoting lever **94**, a link **95**, and a rotatable handle **96**. The pivoting lever **94** is pivoted generally at its middle to the housing **26** at location **97**. One end of the pivoting lever **94** includes teeth **98** that engage teeth **90** of cam **86**. The other end of lever **94** is pivoted to rigid link **95** at location **97'**. Handle **96** includes a body **101** that is rotatably mounted on tube section **66** of MAS pivot bracket **65**, and further includes a flipper **99** that provides easy grasping to a seated user. A protrusion **100** extends from the body and is pivotally attached to link **95**.

To adjust the back-stop mechanism **36**, the handle **96** is rotated, which rotates cam **86** through operation of link **95** and lever **94**. The cam **86** is rotated to a desired angular position so that the selected step **87** engages the seat-attached bracket **56** to prevent any further recline beyond the defined back-stop point. Since the seat **24** is attached to the back frame **30**, this limits recline of the back **22**.

A modified control for operating the back-stop cam **86** is shown in FIG. **11A**. The modified control includes a pivoting lever **94A** and rotatable handle **96A** connected to the handle **96A** by a rotary pivot/slide joint **380**. The lever **94A** includes teeth **381** that engage cam **86** and is pivoted to housing **26** at pivot **97**, both of which are like lever **94**. However, in the modified control, link **95** is eliminated and replaced with the single joint **380**. Joint **380** includes a ball **381** (FIG. **11B**) that extends from the lever **94A**. A snap-on "car" or bearing **382** includes a socket **383** for pivotally engaging ball **381** to define a ball-and-socket joint. The bearing **382** includes outer surfaces **384** that slidably engage a slot **385** in a radially-extending arm **386** on handle **96A** (FIG. **11C**). The joint **380** operably connects the handle **96A** to the lever **94A**, despite the complex movement resulting from rotation of the handle **96A** about a first axis, and from rotation of the lever **94A** about a second axis that is skewed relative to the first axis. Advantageously, the modified control provides an operable interconnection with few parts, and with parts that are partially inside of the control housing **26**, such that the

parts are substantially hidden from view to a person standing beside the chair.

The back frame **30** and back shell **31** (FIG. 12) form a compliant back support for a seated user that is particularly comfortable and sympathetic to back movements of the seated user, particularly in the lumbar area of the back **22**. Adjustment features on the assembly provide further comfort and allow a seated user to customize the chair to meet his/her particular needs and preferences in the upright through reclined positions.

The back frame **30** (FIG. 12A) is curvilinearly shaped and forms an arch across the back area of the chair **20**. A variety of constructions are contemplated for back frame **30**, and accordingly, the present invention should not be improperly limited to only a particular one. For example, the back frame **30** could be entirely metal, plastic, or a combination thereof. Also, the rigid internal reinforcement **102** described below could be tubular, angle iron, or a stamping. The illustrated back frame **30** includes a looping or arch-shaped internal metal reinforcement **102** and an outer molded-on polymeric skin or covering **103**. (For illustrative purposes, the covering **103** is shown as if it is transparent (FIG. 12A), so that the reinforcement **102** is easily seen.) The metal reinforcement **102** includes a looping intermediate rod section **104** (only half of which is shown in FIG. 12A) having a circular cross section. Reinforcement **102** further configured ends/brackets **105** welded onto the ends of the intermediate section **104**. One or two of T-shaped top pivot connectors **107** are attached to intermediate section **104** near a top portion thereof. Notably, a single top connector **107**, when used, allows greater side-to-side flexibility than with two top connectors, which may be desired in a chair where the user is expected to often twist their torso and lean to a side in the chair. A pair of spaced-apart top connectors **107** provide a stiffer arrangement. Each connector **107** (FIG. 12B) includes a stem **108** welded to intermediate section **104** and includes a transverse rod section **109** extended through stem **108**. The rod section **109** is located outboard of the skin or shell **103** and is adapted to snap-in frictionally and pivotally engage a mating recess in the back shell **31** for rotation about a horizontal axis, as described below. The present invention is contemplated to include different back frame shapes. For example, the inverted U-shaped intermediate section **104** of back frame **30** can be replaced with an inverted T-shaped intermediate section having a lower transverse member that is generally proximate and parallel the belt bracket **132**, and a vertical member that extends upwardly therefrom. In a preferred form, each back frame of the present chair defines spaced-apart lower connections or apertures **113** that define pivot points and a top connection(s) **107** forming a triangular tripod-like arrangement. This arrangement combines with the semi-rigid resiliently-flexible back shell **31** to posturally flexibly support and permit torsional flexing of a seated user's torso when in the chair. In an alternative form, the lower connections **113** could occur on the seat instead of the back of the chair.

The configured ends **105** include an inner surface **105'** (FIG. 13) that may or may not be covered by the outer shell **103**. In the illustrated back frame **30** of FIGS. 12A and 4A, the reinforcement **102** is substantially covered by the shell **103**, but a pocket is formed on an inside surface at configured ends **105** at apertures **111–113**. The configured ends **105** include extruded flanges forming apertures **111–113** which in turn define the back-tilt axis **23**, the seat-tilt axis **25**, and a bottom pivotal connection for the back shell **31**, respectively. The apertures **111** and **112** (FIG. 13) include frustoconically-shaped flanges **116** defining pockets for

receiving multi-piece bearings **114** and **115**, respectively. Bearing **114** includes an outer rubber bushing **117** engaging the flanges **116** and an inner lubricous bearing element **118**. A pivot stud **119** includes a second lubricous bearing element **120** that matingly slidingly engages the first bearing element **118**. The stud **119** is extended through bearing **114** in an outward direction and threadably into welded nut **51** on side arms **49** of the base frames **26, 45, and 49**. The bearing element **118** bottoms out on the nut **51** to prevent over-tightening of the stud **119**. The head of the stud **119** is shaped to slide through the aperture **111** to facilitate assembly by allowing the stud to be threaded into nut **51** from the inboard side of the side arm **49**. It is noted that the head of stud **119** can be enlarged to positively capture the configured end **105** to the side arm **49** if desired. The present arrangement including the rubber bushings **117** allows the pivot **23** to flex and compensate for rotation that is not perfectly aligned with the axis **23**, thus reducing the stress on the bearings and reducing the stress on components of the chair such as on the back frame **30** and the side arms **49** where the stud **119** is misaligned with its axis.

The lower seat-to-back frame bearing **115** is similar to bearing **114** in that bearing **115** includes a rubber bushing **121** and a lubricous bearing element **122**, although it is noted that the frustoconical surface faces inwardly. A welded stud **123** extends from seat carrier **124** and includes a lubricous bearing element **125** for rotatably and slidably engaging the bearing element **122**. It is noted that in the illustrated arrangement, the configured end **105** is trapped between the side arms **49** of base frames **26, 45, and 49** and the seat carrier **124**, such that the bearings **114** and **115** do not need to be positively retained to the configured ends **105**. Nonetheless, a positive bearing arrangement could be readily constructed on the pivot **112** by enlarging the head of the stud **119** and by using a similar headed stud in place of the welded stud **123**.

A second configuration of the configured end of back frame **30** is shown in FIG. 13A. Similar components are identified by identical numbers, and modified components are identified with the same numbers and with the addition of the letter "A." In the modified configured end **105A**, the frustoconical surfaces of pivots **111A** and **112A** face in opposite directions from pivots **111** and **112**. Pivot **112A** (including a welded-in stud **123A** that pivotally supports the seat carrier **124** on the back frame **30**) includes a threaded axial hole in its outer end. A retainer screw **300** is extended into the threaded hole to positively retain the pivot assembly together. Specifically, a washer **301** on screw **300** engages and positively retains the bearing sleeve **125** that mounts the inner bearing element **122** on the pivot stud **123A**. The taper in the pocket and on the bearing outer sleeve **121** positively holds the bearing **115A** together. The upper pivot **111A** that pivotally supports the back frame **30** on the side arms **50** of the base frame is generally identical to the lower pivot **112**, except that the pivot **111A** faces in an opposite inboard direction. Specifically, in upper pivot **111A**, a stud **119A** is welded onto side arm **50**. The bearing is operably mounted on the stud **119A** in the bearing pocket defined in the base frame **30** and held in place with another washered screw **300**. For assembly, the back frame **30** is flexed apart to engage bearing **115**, and the configured ends **105A** are twisted and resiliently flexed, and thereafter are released such that they spring back to an at-rest position. This arrangement provides a quick assembly procedure that is fastenerless, secure, and readily accomplished.

The present back shell system shown in FIGS. 12, 15, and 16 (and the back systems of FIGS. 12D–12I) is compliant

and designed to work very sympathetically with the human back. The word “compliant” as used herein is intended to refer to the flexibility of the present back in the lumbar area (see FIGS. 12 and 12F–12I) or a back structure that provides the equivalent of flexibility (see FIGS. 12D and 12E), and the word “sympathetically” is intended to mean that the back moves in close harmony with a seated user’s back and posturally supports the seated user’s back as the chair back **22** is reclined and when a seated user flexes his/her lower back. The back shell **31** has three specific regions, as does the human back, those being the thoracic region, the lumbar region, and the pelvic region.

The thoracic “rib cage” region of a human’s back is relatively stiff. For this reason, a relatively stiff upper shell portion (FIG. 12) is provided that supports the relatively stiff thoracic (rib cage) region **252** of a seated user. It carries the weight of a user’s torso. The upper pivot axis is strategically located directly behind the average user’s upper body center of gravity, balancing his/her back weight for good pressure distribution.

The lumbar region **251** of a human’s back is more flexible. For this reason, the shell lumbar region of back shell **31** includes two curved, vertical-living hinges **126** at its side edges (FIG. 15) connected by a number of horizontal “cross straps” **125**. These straps **125** are separated by widthwise slots **125'** allowing the straps to move independently. The slots **125'** may have radiused ends or teardrop-shaped ends to reduce concentration of stress. This shell area is configured to comfortably and posturally support the human lumbar region. Both side straps **125** are flexible and able to substantially change radius of curvature from side to side. This shell region automatically changes curvature as a user changes posture, yet maintains a relatively consistent level of support. This allows a user to consciously (or subconsciously) flex his/her back during work, temporarily moving stress off of tiring muscles or spinal disc portions onto different ones. This frequent motion also “pumps” nutrients through the spine, keeping it nourished and more healthy. When a specific user leans against the shell **31**, he/she exerts unique relative pressures on the various lumbar “cross straps.” This causes the living hinges to flex in a unique way, urging the shell to conform with a user’s unique back shape. This provides more uniform support over a larger area of the back improving comfort and diminishing “high pressure points.” The cross straps can also flex to better match a user’s side-to-side shape. The neutral axis of the human spine is located well inside the back. Correspondingly, the “side straps” are located forward of the central portion of the lumbar region (closer to the spine neutral axis), helping the shell flexure mimic human back flexure.

The pelvic region **250** is rather inflexible on human beings. Accordingly, the lowest portion of the shell **31** is also rather inflexible so that it posturally/mateably supports the inflexible human pelvis. When a user flexes his/her spine rearward, the user’s pelvis automatically pivots about his/her hip joint and the skin on his/her back stretches. The lower shell/back frame pivot point is strategically located near but a bit rearward of the human hip joint. Its nearness allows the shell pelvic region to rotate sympathetically with a user’s pelvis. By being a bit rearward, however, the lumbar region of the shell stretches (the slots widen) somewhat less than the user’s back skin, enough for good sympathetic flexure, but not so much as to stretch or bunch up clothing.

Specifically, the present back shell construction **31** (FIG. 4A) comprises a resiliently-flexible molded sheet made from polymeric material such as polypropylene, with top and

bottom cushions positioned thereon (see FIG. 4A). The back shell **31** (FIG. 16) includes a plurality of horizontal slots **125'** in its lower half that are located generally in the lumbar area of the chair **20**. The slots **125'** extend substantially across the back shell **31**, but terminate at locations spaced from the sides so that resilient vertical bands of material **126** are formed along each edge. The bands of material or side straps **126** are designed to form a naturally forwardly-convex shape, but are flexible so that they provide an optimal lumbar support and shape to a seated user. The bands **126** allow the back shell to change shape to conform to a user’s back shape in a sympathetic manner, side to side and vertically. A ridge **127** extends along the perimeter of the shell **31**. A pair of spaced-apart recesses **128** are formed generally in an upper thoracic area of the back shell **31** on its rearward surface. The recesses **128** (FIGS. 14A and 14B) each include a T-shaped entrance with the narrow portion **129** of the recesses **128** having a width for receiving the stem **108** of the top connector **32** on the back frame **30** and with the wider portion **130** of the recesses **128** having a width shaped to receive the transverse rod section **109** of the top connector **32**. The recesses **128** each extend upwardly into the back shell **31** such that opposing flanges **131** formed adjacent the narrow portion **129** pivotally capture the rod section **109** of the T-top connector **107** as the stem **108** slides into the narrow portion **129**. Ridges **132** in the recesses **128** frictionally positively retain the top connectors **107** and secure the back shell **31** to the back frame **30**, yet allow the back shell **31** to pivot about a horizontal axis. This allows for the back shell **31** to flex for optimal lumbar support without undesired restriction.

A belt bracket **132** (FIG. 16) includes an elongated center strip or strap **133** that matches the shape of the bottom edge of the back shell **31** and that is molded into a bottom edge of the back shell **31**. The strip **133** can also be an integral part of the back shell or can be attached to back shell **31** with screws, fasteners, adhesive, frictional tabs, insert-molding techniques, or in other ways of attaching known in the art. The strip **133** includes side arms/flanges **134** that extend forwardly from the ends of strip **133** and that include apertures **135**. The torsional adjustment lumbar mechanism **34** engages the flanges **134** and pivotally attaches the back shell **31** to the back frame at location **113** (FIG. 4A). The torsional adjustment lumbar spring mechanism **34** is adjustable and biases the back shell **31** to a forwardly-convex shape to provide optimal lumbar support for a seated user. The torsional adjustment lumbar spring mechanism **34** cooperates with the resilient flexibility of the back shell **31** and with the shape-changing ability of the vertically-adjustable lumbar support **35** to provide a highly-adjustable and comfortable back support for a seated user.

The pivot location **113** is optimally chosen to be at a rear of the hip bone and somewhat above the seat **24**. (See FIG. 12.) Optimally, the fore/aft distance from pivot locations **113** to strip **133** is approximately equal to the distance from a seated user’s hip joint/axis to their lower spine/tail bone region so that the lower back **250** moves very similarly and sympathetically to the way a seated user’s lower back moves during flexure about the seated user’s hip joint. The location **113** in combination with a length of the forwardly-extending side flanges **133** causes back shell **31** to flex in the following sympathetic manner. The pelvic supporting area **250** of the back shell construction **31** moves sympathetically rearwardly and downwardly along a path selected to match a person’s spine and body movement as a seated user flexes their back and presses their lower back against the back shell construction **31**. The lumbar support area **251** simulta-



neously flexes from a forwardly-concave shape toward a more planar shape. The thoracic support area **252** rotates about top connector **107** but does not flex a substantial amount. The total angular rotation of the pelvic and thoracic supporting areas **250** and **252** are much greater than in prior art synchrotilt chairs, which provides substantially increased support. Notably, the back shell construction **31** also flexes in a horizontal plane to provide good postural support for a seated user who twists his/her torso to reach an object. Notably, the back frame **30** is oriented at about a 5° rearward angle from vertical when in the upright position, and rotates to about a 30° rearward angle from vertical when in the fully reclined position. Concurrently, the seat-tilt axis **25** is rearward and at an angle of about 60° below horizontal from the back-tilt axis **23** when the back frame **30** is in the upright position, and pivots to almost vertically below the back-tilt axis **23** when the back frame **30** is in the fully reclined position.

Back constructions **31A–31F** (FIGS. **12D–12I**, respectively) are additional constructions adapted to provide a sympathetic back support similar in many aspects to the back shell construction **31**. Like back construction **31**, the present invention is contemplated to include attaching back constructions **31A–31F** to the seat or the base frame at bottom connections. Specifically, the illustrated constructions **31A–31F** are used in combination with back frame **30** to provide a specific support tailored to thoracic, lumbar, and pelvic regions of a seated user. Each of the back constructions **31A–31F** are pivoted at top and bottom pivot connections **107** and **113**, and each include side arms **134** for flexing about a particularly located lever pivot axis **113**. However, the back constructions **31A–31F** achieve their sympathetic back support in slightly different ways.

Back construction **31A** (FIG. **12D**) includes a cushioned top back support **255** pivoted at top pivot connection **107**, and further includes a cushioned bottom back support **256** pivoted at bottom location **113** by the belt bracket **132** including side flanges **134**. Top and bottom back supports **255** and **256** are joined by a pivot/slide connection **257**. Pivot/slide connection **257** comprises a bottom pocket formed by a pair of flanges **258**, and top flange **259** that both slides and pivots in the pocket. A torsional lumbar support spring mechanism **34** is attached at bottom pivot location **113** and, if desired, also at connection **107** to bias top and bottom back supports **255** and **256** forwardly. The combination provides a sympathetic back support that moves with a selected user's back to match virtually any user's back shape, similar to the back shell construction **31** described above.

Back construction **31B** (FIG. **12E**) includes a top back support **261** pivoted at top connection **107**, a bottom back support **262** pivoted at lower connection **113** on belt bracket side flange **134**, and an intermediate back support **262** operably positioned therebetween. Intermediate back support **262** is pivoted to bottom back support **262** at pivot **263**, and is slidably pivoted to top back support **261** at pivot/slide joint **264**. Pivot/slide joint **264** is formed by top flanges **265** defining a pocket, and another flange **266** with an end that pivots and slides in the pocket. Springs are positioned at one or more joints **107**, **113**, and **264** to bias the back construction **260** to a forwardly-concave shape.

Back construction **31C** (FIG. **12F**) is similar to back shell construction **31** in that it includes a sheet-like flexible shell with transverse lumbar slits. The shell is pivoted at top and bottom connections **107** and **113** to back frame **30**. The shell of back construction **31C** is biased toward a forwardly-convex shape by a torsion spring mechanism **34** at bottom

pivot **113** and at top pivot **107**, by a curvilinear leaf spring **271** in the lumbar area of the shell, by a spring **272** that presses the shell forwardly off of an intermediate section of back frame **30**, and/or by a vertical spring **273** that extends from top connection **107** to a rear pivot on belt bracket side flange **134**.

Back construction **31D** (FIG. **12G**) includes a transverse leaf spring **276** that spans between the opposing sides of back frame **30**, and that biases the lumbar area of its back shell **277** forwardly, much like spring **272** in the back construction **270**. Back construction **31E** (FIG. **12H**) includes vertical leaf springs **279** embedded in its back shell **280** that bias the lumbar area of back shell **280** forwardly, much like springs **271** in back construction **270**. Notably, back construction **278** includes only a single top pivot connection **107**. Back construction **31F** (FIG. **12I**) includes a vertical spring **282** connected to a top of the back frame **30**, and to belt bracket **132** at a bottom of its back shell **283**. Since the back shell **283** is forwardly convex, the spring **282** biases the shell **283** toward an even more convex shape, thus providing additional lumbar support. (Compare to spring **273** on back construction **31C**, FIG. **12F**.)

It is contemplated that the torsional lumbar support spring mechanism **34** (FIG. **12I**) can be designed in many different constructions, but includes at least a spring operably connected between the back frame **30** and the back shell **31**. Optionally, the arrangement includes a tension adjustment device having a handle and a friction latch to provide for tension adjustment. The spring biases the belt bracket **132** rotationally forward so that the back shell **31** defines a forwardly-convex shape optimally suited for lumbar support to a seated user. By rotating the handle to different latched positions, the tension of the spring is adjusted to provide an optimal forward lumbar force. As a seated user presses against the lumbar area of back shell **31**, the back shell **31** flexes "sympathetically" with a movement that mirrors a user's spine and body flesh. The force of the bands of material **126** in the shell **31** provide a relatively constant force toward their natural curvilinear shape, but when combined with the torsional lumbar support spring mechanism **34**, they provide a highly-adjustable bias force for lumbar support as the user leans against the lumbar area. It is noted that a fixed non-adjustable spring biasing the back belt or the back shell flex zone directly could be used, or that an adjustable spring only adjustable during installation could be used. However, the present adjustable device allows the greatest adjustment to meet varying needs of seated users. Thus, a user can assume a variety of well-supported back postures.

In the present torsional lumbar support spring mechanism **34** (FIG. **12I**), belt bracket **132** is pivoted to back frame **30** by a stud **290** that extends inboard from back frame **30** through a hole **291** in belt bracket side flange **134**. A bushing **292** engages the stud **290** to provide for smooth rotation, and a retainer **293** holds the stud **290** in hole **291**. A base **294** is screwed by screws **294'** or welded to back frame **30**, and includes a protrusion **295** having a sun gear **296** and a protruding tip **297** on one end. A hub **298** includes a plate **299** with a sleeve-like boss **300** for receiving the protrusion **295**. The boss **300** has a slot **301** for receiving an inner end **302** of a spiral spring **303**. The body of spring **303** wraps around protrusion **295**, and terminates in a hooked outer end **304**. Hub **298** has a pair of axle studs **305** that extend from plate **299** in a direction opposite boss **300**. A pair of pie-shaped planet gears **306** are pivoted to axle studs **305** at pivot holes **307**. A plurality of teeth **308** are located in an arch about pivot holes **307** on the planet gears **306**, and a

driver pin **309** is located at one end of the arc. A cup-shaped handle **310** is shaped to cover gears **306**, hub **298**, spring **303**, and base **294**. The handle **310** includes a flat end panel **311** having a centered hole **312** for rotatably engaging the protruding tip **297** of base **294**. A pair of opposing spirally-shaped recesses or channels **313** are formed in the end panel **311**. The recesses **313** include an inner end **314**, an outer end **315**, and an elongated portion having a plurality of detents or scallops **316** formed between the ends **314** and **315**. The recesses **313** mateably receive the driver pins **309**. The hooked outer end **304** engages fingers **317** on belt bracket **132**, which fingers **317** extend through an arcuate slot **318** in the configured end **105** of back frame **30**.

Handle **310** is rotated to operate torsional lumbar support spring mechanism **34**. This causes recesses **313** to engage driver pins **309** on planet gears **306**. The planet gears **306** are geared to sun gear **296**, such that planet gears **306** rotate about sun gear **296** as the driver pins **309** are forced inwardly (or outwardly) and the planet gears **306** are forced to rotate on their respective pivots/axles **305**. In turn, as planet gears **306** rotate, they force hub **298** to rotate. Due to the connection of spiral spring **303** to hub **298**, spiral spring **303** is wound tighter (or unwound). Thus, the tension of spring **303** on belt bracket **132** is adjustably changed. The detents **316** engage the driver pins **309** with enough frictional resistance to hold the spring **303** in a desired tensioned condition. Due to the arrangement, the angular winding of spiral spring **303** is greater than the angular rotation of handle **310**.

In a modified torsional lumbar support spring mechanism **34A** (FIG. 12K), a base bracket **244A** is attached to configured end **105A** of back frame **30**. A lever **306A** and driver **298A** are operably mounted on base bracket **244A** to wind a spiral spring **303A** as a handle **310A** is rotated. Specifically, the base bracket **244A** includes a pivot pin **290** that pivotally engages hole **291** in belt bracket **132**. A second pin **317** extends through arcuate slot **318** in configured end **105A**, which slot **318** extends around pivot pin **290** at a constant radius. Two pins **360** and **361** extend from base bracket **244A** opposite pivot pin **290**. The driver **298A** includes an apertured end **362** with a bore **363** for rotatably engaging center pin **360**. The end **362** includes an outer surface **364** with a slot therein for engaging an inner end **365** of spiral spring **303A**. The outer end **365** is hook-shaped to securely engage pin **317** on the belt bracket **132**. A finger-like stud **366** extends laterally from the outer end **367** of driver **298A**.

Lever **306A** includes a body with a hole **368** for pivotally engaging pin **361**, and a slot **369** extending arcuately around hole **368**. A pin **370** extends from lever **306A** for engaging a spiral cam slot **313A** on an inside surface of cup-shaped handle **310A**. A tooth **371** on lever **306A** is positioned to engage stud **366** on driver **298A**. Hole **372** on handle **310A** rotatably engage the pivot pin **360** on base bracket **244A**.

Handle **310A** is rotatable between a low tension position (FIGS. 12L and 12LL) and a high tension position (FIGS. 12M and 12MM). Specifically, as handle **310A** is rotated, pin **370** rides along slot **313A** causing lever **306A** to rotate about hole **368** and pivot pin **361**. As lever **306A** rotates, tooth **371** engages pin **366** to rotate driver **298A** about pin **360**. Rotation of driver **298A** causes the inside end **365** of spring **303A** to rotate, thus winding (or unwinding) spring **303A**. The arrangement of driver **298A**, lever **306A**, and handle **310A** provide a mechanical advantage of about 4:1, so that the spiral spring **303A** is adjustably wound with a desired amount of adjustment force on the handle **310A**. In the illustration, a rotation of about 330° of the handle **310A** produces a spring tension adjustment winding of about 80°.

Optionally, for maximum adjustability, a vertical adjustable lumbar system **35** (FIG. 16) is provided that includes a slide frame **150** (FIG. 19) that is generally flat and that includes several hooked tabs **151** on its front surface. A concave lumbar support sheet **152** (FIG. 16) of flexible material such as spring steel includes a plurality of vertical slots that form resilient leaf-spring-like fingers **153** along the top and bottom edges of the sheet **152**. The (optional) height adjustable back support sheet **152** is basically a radiused sheet spring that can, with normal back support pressures, deflect until it matches the shape of the back shell beneath it. In doing so, it provides a band of higher force across the back. This provides a user with height-adjustable localized back support, regardless of the flexural shape of the user's back. Thus, it provides the benefits of a traditional lumbar height adjustment without forcing a user into a particular rigid back posture. Further, the fabric or upholstery on the back is always held taut, such that wrinkles are eliminated. Stretch fabric can also be used to eliminate wrinkles.

A user may also use this device for a second reason, that reason being to more completely adapt the back shell shape to his/her own unique back shape. Especially in the lower lumbar/pelvic region, humans vary dramatically in back shape. User's with more extreme shapes will benefit by sliding the device into regions where their back does not solidly contact the shell. The device will effectively change its shape to exactly "fill in the gap" and provide good support in this area. No other known lumbar height adjustor does this in the manner described below.

Four tips **154** on fingers **153** form retention tabs that are particularly adapted to securely engage the hooked tabs **151** to retain the sheet **152** to the slide frame **150**. The remaining tips **155** of the fingers **153** slidably engage the slide frame **150** and hold the central portion **156** of the concave sheet forwardly and away from the slide frame **150**. The slide frame **150** is vertically adjustable on the back shell **31** (FIG. 16) and is positioned on the back shell **31** between the back shell **31** and the back cushion. Alternatively, it is contemplated that the slide frame **150** could be located between the back cushion and under the upholstery covering the back **22**, or even on a front face of the back **22** outside the upholstery sheet covering the back **22**. By adjusting the slide vertically, this arrangement allows a seated user to adjust the shape of the lumbar area on the back shell **31**, thus providing a high degree of comfort. A laterally-extending guide **157** (FIG. 19) is formed at each of the ends of the slide frame **150**. The guides **157** include opposing flanges **158** forming inwardly-facing grooves. Molded handles **159** (FIG. 20) each include a leg **160** shaped to mateably telescopingly engage the guides **157** (FIGS. 17 and 18). The handles **159** further include a C-shaped lip **160** shaped to snappingly engage and slide along the edge ridge **127** along the edge of back shell **31**. It is contemplated that other means can be provided for guiding the vertical movement of the slide frame **150** on back shell **31**, such as a cord, a track molded along but inward of the edge of the back shell, and the like. An enlarged flat end portion **161** of handle **159** extends laterally outwardly from molded handle **159**. Notably, the end portion **161** is relatively thin at a location **161'** immediately outboard of the lip **160**, so that the handle **159** can be extended through a relatively thin slot along the side edge of the back **22** when a cushion and upholstery sheet are attached to the back shell **31**.

The illustrated back **22** of FIG. 12 includes a novel construction incorporating stretch fabric **400** sewn at location **401** to a lower edge of the upholstery sheet **402** for covering a front of the back **22**. The stretch fabric **400** is

further sewn into a notch 406 in an extrusion 403 of structural plastic, such as polypropylene or polyethylene. The extrusion 403 is attached to a lower portion 404 of the back shell 31 by secure means, such as snap-in attachment, hook-in attachment, rivets, screws, other mechanical fasteners, or other means for secure attachment. The foam cushion 405 of the back 22 and the vertically-adjustable lumbar support device 35 are positioned between the sheet 402 and back shell 31. It is contemplated that the stretch fabric will have a stretch rate of at least about 100%, with a recovery of at least 90% upon release. The stretch fabric 400 and sheet 402 are sewn onto the back 22 in a tensioned condition, so that the sheet 402 does not wrinkle or pucker despite the large flexure of the lumbar region 251 toward a planar condition. The stretch fabric 400 is in a low visibility position, but can be colored to the color of the chair if desired. It is noted that covering 402 can be extended to cover the rear of back 22 as well as its front.

#### Primary Seat Movement, Seat Undercarriage/Support Frame and Bearing Arrangement

The seat 24 (FIG. 4B) is supported by an undercarriage that includes a seat front slide 162 and the seat carrier 124. Where seat depth adjustment is desired, a manually depth-adjustable seat frame 163 is slidably positioned on the seat carrier 124 (as is shown in FIGS. 4B and 21–30). Where seat depth adjustment is not desired, the features of the seat frame 163 and seat rear carrier 124 can be incorporated into a single component, such as is illustrated in FIG. 29 by frame member 163'. A seat shell 164 (FIG. 4B) includes a buttock-supporting rear section 165 that is positioned on the seat carrier 124. The buttock-supporting rear section 165 carries most of the weight of the seated user, and acts somewhat like a perch in this regard. The seat shell 164 further includes a thigh-supporting front section 166 that extends forwardly of the seat frame 163. Front section 166 is connected to rear section 165 by a resilient section 167 strategically located generally under and slightly forward of a seated user's hip joint. The resilient section 167 has a plurality of transverse slots 168 therein. The slots 168 are relatively short and are staggered across the seat shell 164, but are spaced from the edges of the seat shell 164, such that the band of material 169 at the edges of the seat shell 164 remains intact and uninterrupted. The bands 169 securely connect the front and rear sections 166 and 165 together and bias them generally toward a planar condition. A seat cushion 170 is positioned on seat frame 163 and is held in place by upholstery sheet and/or adhesive or the like.

Slide 162 (FIG. 4B) includes a top panel 171 with C-shaped side flanges 172 that extend downwardly and inwardly. A linear lubricous cap 173 is attached atop each sidewall of housing 26 and a mating bearing 174 is attached inside of C-shaped side flanges 172 for slidably engaging the lubricous cap 173. In this way, the slide 162 is captured on the housing 26 for fore-to-aft sliding movement. The seat-attached bracket 56 is attached under the top panel 171 and is located to operate with the back-stop mechanism 36. An axle 174' is attached atop the top panel 171 and includes ends 175 that extend laterally from the slide 162.

Seat carrier 124 (FIG. 4B) is T-shaped in plan view. Seat carrier 124 is stamped from sheet metal into a "T" shape, and includes a relatively wide rear section 176 and a narrower front section 177. Embossments such as elongated embossments 178, 179, and 180 are formed in sections 176 and 177 along with side-down flanges 181 and side-up flanges 182 to stiffen the component. Two spaced-apart stop tabs 183 and a series of latch apertures 184 are formed in the front section 177 for reasons discussed below. The welded studs 123 are

attached to side-up flanges 182 and extend laterally. As discussed above, the studs 123 define the seat-tilt axis 25 at this location.

Seat frame 163 (FIG. 4B) is T-shaped, much like the seat carrier 124, but seat frame 163 is shaped more like a pan and is generally larger than the seat carrier 124 so that it is better adapted to support the seat shell 164 and seat cushion 170. Seat frame 163 includes a front portion 185 and a rear portion 186. The front portion 185 includes a top panel 187 with down flanges 188 at its sides. Holes 189 at the front of down flanges 188 form a pivot axis for the active thigh flex device 190 described below. Other holes 191 spaced rearwardly of the holes 189 support an axle that extends laterally and supports a multi-functional control 192 for controlling the seat depth adjustment and for controlling the active thigh flex device 190. The center of front portion 185 is raised and defines a sidewall 193 (FIG. 23) having three apertures 194–196 that cooperate to pivotally and operably support a depth latch 197. A depression 198 is formed in the center of front portion 185 and a slot 200 is cutout in the center of the depression 198. A T-shaped stop limiter 199 (FIG. 26) is positioned in the depression 198 and screw-attached therein, with the stem 201 of the limiter 199 extending downwardly through the slot 200 (FIGS. 26 and 26A). An inverted U-shaped bracket 203 is attached to the wide rear section 176. The U-bracket 203 (FIG. 28) includes apertures for pivotally supporting one end of a gas spring 204 used in the active thigh flex support device 190 described below. The rear section 176 (FIG. 23) includes a U-shaped channel section 205 that extends around its perimeter and an outermost perimeter flange 206, both of which serve to stiffen the rear section 176. Flat areas 205' are formed on opposing sides of the rear section 176 for slidably engaging the top of rear bearings 209.

#### Seat Depth Adjustment

A pair of parallel elongated brackets 207 (FIG. 4B) are attached under the forwardly-extending outer sides of the U-shaped channel section 205 for slidably supporting the seat frame 163 on the seat carrier 124. The elongated Z-brackets 207 form inwardly-facing C-shaped guides or tracks (FIG. 21) that extend fore-to-aft under the seat frame 163. A bearing member is attached inside the guides of bracket 207 to provide for smooth operation if desired. Two spaced-apart front bearings 208 (FIG. 4B) and two spaced-apart rear bearings 209 are attached atop the seat carrier 124, front bearings 208 being attached to front section 177, and rear bearings 209 being attached to rear section 176. The rear bearings 209 are configured to slidably engage the guides in brackets 207, and further include a tongue 210 that extends inwardly into the C-shaped portion of the C-shaped guides. The tongue 210 captures the seat frame 163 so that the seat frame 163 cannot be pulled upwardly away from the seat carrier 124. The front bearings 208 slidably engage the underside of the front section 187 at spaced-apart locations. The front bearings 208 can also be made to capture the front portion of the seat frame 163; however, this is not deemed necessary due to the thigh flex device which provides this function.

The depth adjustment of seat 24 is provided by manually sliding seat frame 163 on bearings 208 and 209 on seat carrier 124 between a rearward position for minimum seat depth (see FIG. 24) and a forward position for maximum seat depth (see FIG. 25). The stem 201 (FIG. 26A) of limiter 199 engages the stop tabs 183 in seat carrier 124 to prevent the seat 24 from being adjusted too far forwardly or too far rearwardly. The depth latch 197 (FIG. 23) is T-shaped and includes pivot tabs 212 and 212' on one of its arms that

pivotaly engages apertures 194 and 195 in seat frame 163. The depth latch 197 further includes a downwardly-extending latching tooth 213 on its other arm that extends through aperture 195 in seat frame 163 into a selected one of the series of slots 214 (FIG. 26) in the seat carrier 124. A "stem" of the depth latch 197 (FIG. 23) extends laterally outboard and includes an actuation tab 215. Multi-function control 192 includes an inner axle 217 that supports the main components of the multi-function control. One of these components is an inner sleeve 218 rotatably mounted on axle 217. The handle 219 is connected to an outer end of the inner sleeve 218 and a protrusion 220 is connected to an inner end of the inner sleeve 218. The protrusion 220 is connected to the actuation tab 215, such that rotation of the handle 219 moves the protrusion 220 and pivots the latch 197 about latch pivots 194 and 195 in an up and down disconnection. The result is that the latching tooth 213 is released from the series of slots 214, so that the seat 24 can be adjusted to a new desired depth. A spring on inner sleeve 218 biases the latch 197 to a normally engaged position. It is contemplated that a variety of different spring arrangements can be used, such as by including an internal spring operably connected to inner sleeve 218 or to latch 197.

Seat Active Thigh Angle Adjustment (with Infinitely Adjustable Gas Spring)

A front reinforcement plate 222 (FIG. 28) is attached to the underside of the thigh-supporting front section 166 of seat shell 164. A Z-shaped bracket 221 is attached to plate 222 and a bushing 223 is secured between the bracket 221 and the plate 222. A bent rod axle 224 is rotatably supported in bushing 223 and includes end sections 225 and 226 that extend through and are pivotaly supported in apertures 190 of down flanges 189 of seat frame 163. The end section 226 includes a flat side, and a U-shaped bracket 227 is non-rotatably attached to the end section 226 for supporting an end of gas spring 204. The U-shaped bracket 227 is oriented at an angle to a portion of the bent rod axle 224 that extends toward bushing 223, such that the U-shaped bracket 227 acts as a crank to raise and lower the thigh-supporting front portion 166 of seat shell 164 when the gas spring 204 is extended or retracted. Specifically, the gas spring 204 is operably mounted between brackets 227 and 203, so that when extended, the front thigh-supporting section 166 of seat shell 164 is moved upwardly to provide additional thigh support. Notably, the thigh-supporting section 166 provides some flex even when the gas spring 204 is locked in a fixed extension, so that a person's thighs are comfortably supported at all times. Nonetheless, the infinite adjustability of this active thigh support system provides an improved adjustability that is very useful, particularly to people with shorter legs.

The gas spring 204 (FIG. 28) is self-locking and includes a release button 233 at its rear end that is attached to the bracket 203 for releasing the gas spring 204 so that its extendable rod is extendable or retractable. Such gas springs 204 are well-known in the art. The multi-functional control 192 (FIG. 3) includes an actuator for operating the release button 233. Specifically, the multi-functional control 192 includes a rotatably outer sleeve 229 (FIG. 23) operably positioned on the inner sleeve 218 and a handle 230 for rotating the outer sleeve 229. A connector 231 extends radially from an inboard end of outer sleeve 229. A cable 232 extends from the connector 231 on outer sleeve 229 to the release button 233 (FIG. 28). The cable 232 has a length chosen so that when outer sleeve 229 is rotated, the cable 232 pulls on the release button 233 causing the internal lock of the gas spring 204 to release. The release button 233 is

spring biased to a normally locked position. A seated user adjusts the active thigh flex support system by operating the handle 230 to release the gas spring 204. The seated user then presses on (or raises their legs away from) the thigh-supporting front portion 166 of the seat shell 164 causing the gas spring 230 to operate the bent rod axle 217 to re-adjust the thigh-supporting front portion 166. Notably, the active thigh support system 190 provides for infinite adjustment within a given range of adjustment.

Also shown on the control 192 (FIG. 10) is a second rotatable handle 234 operably connected to a pneumatic vertical height adjustment mechanism for adjusting chair height by a Bowden cable 235, sleeve 235', and side bracket 235". The details of chair height adjustment mechanisms are well known, such that they do not need to be discussed herein.

The seat shell 164 and its supporting structure (FIG. 4B) is configured to flexibly support a seated user's thighs. For this reason, the seat cushion 170 includes an indentation 170A located slightly forwardly of the seated user's hip joint (FIG. 12). The upholstery covering the seat cushion 170B includes a tuck or fold at the indentation 170A to allow the material to expand or stretch during downward flexing of the thigh support region since this results in a stretching or expanding at the indentation due to the fact that the top surface of the upholstery is spaced above the hinge axis of flexure of the seat shell 164. Alternatively, a stretch fabric or separated front and rear upholstered cushions can be used.

Seat Passive/Flexible Thigh Support (without Gas Spring)

A passive thigh flex device 237 (FIG. 30) includes a reinforcing plate 238 attached to the underside of the thigh-supporting front portion 166 of seat shell 164 (FIG. 4B). A pair of L-shaped stop tabs 239 (FIG. 29) are bent downwardly from the body of the plate 238. The L-shaped tabs 239 include horizontal fingers 240 that extend rearwardly to a position where the fingers 240 overlap a front edge 241 of the seat frame 163. Bushings 242 are positioned inside the L-shaped tabs 239 and include a notch 243 engaging the front edge 241. A curvilinearly-shaped leaf spring 244 is positioned transversely under the reinforcing plate 238 with the ends 245 of the leaf spring 244 engaging recesses in the top of the bushings 242. The leaf spring 244 has a curvilinear shape so that it is in compression when in the present passive thigh flex device 237. When a seated user presses downwardly on the thigh-supporting front portion 166 with their thighs, the leaf spring 244 bends in the middle causing the reinforcing plate 238 to move toward the front edge 241 of the seat frame 163. When this occurs, the fingers 240 each move away from their respective bushings 242 (FIG. 31). When the seated user releases the downward pressure on the thigh-supporting front portion 166, the spring 244 flexes toward its natural bent shape causing the bushings 242 to move back into engagement with the fingers 240 (FIG. 30). Notably, this passive thigh flex device 237 allows the user to flex the lateral sides of the thigh-supporting front portion 166 of the seat shell 164 independently or simultaneously. The degree of flexure of the passive thigh flex device 237 is limited by the distance that bushings 242 can be moved in L-shaped tabs 239.

In the foregoing description, it will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims by their language expressly state otherwise.

The invention claimed is:

**1.** A chair comprising:

- a base assembly including a control housing having opposing side flanges and a side pivot located proximate one of the side flanges;
- a back pivoted to the base assembly for movement between upright and reclined positions;
- a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back;
- an energy mechanism for biasing the back toward the upright position, the energy mechanism including an extendable/compressible spring positioned transversely in the control housing with one end supported on one of the side flanges, and further including a lever pivoted to the side pivot, the lever having a spring-engaging portion engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat; and
- the side pivot, the spring-engaging portion, and the seat-biasing portion being spaced from each other and arranged so that the spring biases the lever about a fulcrum located generally at the side pivot to bias the back toward the upright position, wherein the side pivot includes an adjustable pivot member constructed to change a location of the fulcrum on the lever when the pivot member is adjusted.

**2.** The chair defined in claim **1** wherein the base assembly includes a base frame that incorporates the housing.

**3.** The chair defined in claim **1** wherein the pivot member and the lever include interfacing surfaces, at least one of the interfacing surfaces being curvilinear.

**4.** The chair defined in claim **3** wherein the interfacing surfaces include intermeshing teeth.

**5.** The chair defined in claim **4** wherein the lever comprises an L-shaped bell crank, and the fulcrum is located generally along an intermediate portion of one leg of the L-shaped bell crank.

**6.** The chair defined in claim **1** wherein the lever and the pivot member are pivoted about vertical axes and are movable in a common horizontal plane that provides compact positioning within the control housing.

**7.** The chair defined in claim **1** wherein the spring is supported by the control housing and engaged by the lever in a configuration that causes the free end of the spring to simultaneously move toward the one supported end and also move along a fore/aft direction during recline of the back.

**8.** A chair comprising:

- a base assembly including a control housing having opposing side flanges and a side pivot located proximate one of the side flanges;
- a back pivoted to the base assembly for movement between upright and reclined positions;
- a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back;
- an energy mechanism for biasing the back toward the upright position, the energy mechanism including an extendable/compressible spring positioned transversely in the control housing with one end supported on one of the side flanges, and further including a lever pivoted to the side pivot, the lever having a spring-engaging portion engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat;

the side pivot, the spring-engaging portion, and the seat-biasing portion being spaced from each other and

arranged so that the spring biases the lever about a fulcrum located generally at the side pivot to bias the back toward the upright position;

the spring being supported by the control housing and engaged by the lever in a configuration that causes the free end of the spring to simultaneously move toward the one supported end and also move along a fore/aft direction during recline of the back; and

the lever both longitudinally compressing the spring and causing the spring to bend laterally in a non-linear manner during recline of the back.

**9.** In a chair having a control housing including a pivot member, a reclineable back operably connected to the control housing for movement between upright and reclined positions, and an energy source in the control housing for biasing the back toward the upright position, the improvement of an adjustable back tension control comprising:

the pivot member being adjustable; and

a lever engaging the energy source and the pivot member, the lever being operably connected to the back for biasing the back toward the upright position, the lever and the pivot member having non-slip interfacing surfaces, at least one of which is curvilinear, so that the interfacing surfaces engage to define a shifting fulcrum as the lever is rotated during recline of the back, and further so that the fulcrum changes location as the pivot member is adjusted to change a moment arm over which the energy source operates.

**10.** The chair defined in claim **9** wherein the lever comprises a bell crank having a leg that is pivotally engaged at an intermediate location by the pivot member to define the fulcrum.

**11.** The chair defined in claim **10** wherein the lever pivots in a horizontal plane about a generally vertical axis to provide for compact positioning in the control housing.

**12.** The chair defined in claim **11** including a link and a seat-engaging bracket operably connected to the lever by the link so that the lever biases the seat-engaging bracket and the seat in a rearward direction.

**13.** The chair defined in claim **10** wherein the pivot member is pivoted to the control housing at a pivot location spaced from the interfacing surface of the pivot member, the interfacing surface of the pivot member being arcuately shaped and defining a constant radius from the pivot location.

**14.** The chair defined in claim **13** wherein the interfacing surfaces have teeth that engage.

**15.** The chair defined in claim **14** wherein the interfacing surface of the lever also has a curvilinear shape.

**16.** The chair defined in claim **9** including an adjustment mechanism for angularly adjusting the pivot member to change a length of the moment arm.

**17.** The chair defined in claim **16** wherein the adjustment mechanism includes an overtorque device to prevent over-torquing by a user when adjusting the pivot member.

**18.** The chair defined in claim **9** wherein the chair includes a seat operably positioned on the control housing and interconnected between the lever and the back.

**19.** The chair defined in claim **9** wherein the interfacing surfaces have teeth that engage.

**20.** A chair comprising:

- a base assembly;
- a component comprising one of a reclineable back and a movable seat pivoted to the base assembly for movement between first and second positions; and
- a spring with one end supported on the base assembly and another end operably connected to the component, the

spring having a length and, when the component is moved from the first position to the second position, being simultaneously longitudinally compressed along the length and also laterally bent in a direction transverse to the length.

21. The chair defined in claim 20 including a lever having a first end contacting the another end of the spring and a second end linked to the component.

22. The chair defined in claim 21 wherein the lever is pivoted to the base assembly.

23. The chair defined in claim 22 wherein the component comprises the movable seat.

24. The chair defined in claim 23 including a back frame operably connected to the seat for simultaneous movement therewith.

25. The chair defined in claim 20 wherein the base assembly includes a base frame that incorporates the housing.

26. A chair comprising:

a base assembly including a control housing;

a single stored energy source positioned in the control housing providing a compressive force;

a back support operably interconnected with said single energy source for movement between upright and reclined positions, said single stored energy source both exerting pretension to bias the back support toward the upright position and providing resistance to tilting of the back support when reclining; and

a controller for regulating the pretension of the stored energy source and tilt rate of the back support, the controller including a lever defining an adjustable fulcrum point that can be adjusted without overcoming the compressive force of the said single stored energy source.

27. The chair defined in claim 26 including a seat engaging and interconnecting the back support to the energy source.

28. A chair comprising:

a base assembly including a control housing;

a seat slidingly supported on the control housing;

a back frame pivoted to the base assembly for movement between upright and reclined positions and operably attached to the seat so that pivotal movement of the back frame and sliding movement of the seat are synchronized;

the control housing defining a relatively thin, horizontally-extending compartment under the seat; and

an adjustable energy mechanism operably positioned in the compartment, the adjustable energy mechanism including an extensible energy source, a lever operably connected between the energy source and the seat, and an adjustment member adjustably pivotally supporting the lever for adjustably controlling force transmitted from the energy source through the lever to the seat, the energy source, the lever, and the adjustment member being movable in horizontal directions only so as to operate within the relatively-thin horizontally-extending compartment.

29. The chair defined in claim 28 wherein the adjustment member includes a pivot member operably attached to the control housing for shifting the lever to adjust a fulcrum of the lever.

30. The chair defined in claim 28 wherein the base assembly includes a base frame that incorporates the housing.

31. A chair comprising:

a base assembly including a control housing;

a seat slidingly supported on the control housing;

a back frame pivoted to the base assembly for movement between upright and reclined positions and operably attached to the seat so that pivotal movement of the back frame and sliding movement of the seat are synchronized; and

an energy mechanism including a spring having a length and an L-shaped torque member with a first leg engaging an end of the spring and a second leg extending generally parallel the length of the spring, the first leg pivotally engaging the control housing at a location spaced from the end of the spring, and the second leg being operably connected to one of the seat and the back frame so that the spring biases the torque member in a manner biasing the back frame toward the upright position.

32. The chair defined in claim 31 wherein the first leg includes a curvilinear surface that both rollingly and pivotally engages structure on the control housing as the back frame moves between upright and reclined positions.

33. The chair defined in claim 32 wherein the structure on the control housing including a pivot member with an interface surface that engages the curvilinear surface on the first leg, the surfaces being configured to positively engage to prevent undesired slippage.

34. The chair defined in claim 31 wherein the base assembly includes a base frame that incorporates the housing.

35. A chair comprising:

a base assembly including a control housing having opposing side flanges and a side pivot located proximate one of the side flanges;

a back pivoted to the base assembly for movement between upright and reclined positions;

a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back;

an energy mechanism for biasing the back toward the upright position, the energy mechanism including an extendable/compressible spring positioned transversely in the control housing with one end supported on one of the side flanges, and further including a lever pivoted to the side pivot, the lever having a spring-engaging portion engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat; and

the side pivot, the spring-engaging portion, and the seat-biasing portion being spaced from each other and arranged so that the spring biases the lever about a fulcrum located generally at the side pivot to bias the back toward the upright position, wherein the pivot member and the lever include interfacing surfaces, and the interfacing surfaces include intermeshing teeth.

36. A chair comprising:

a base assembly including a control housing having opposing side flanges and a side pivot located proximate one of the side flanges;

a back pivoted to the base assembly for movement between upright and reclined positions;

a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back;

an energy mechanism for biasing the back toward the upright position, the energy mechanism including an

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extendable/compressible spring positioned transversely in the control housing with one end supported on one of the side flanges, and further including a lever pivoted to the side pivot for rotation about a vertical axis of rotation, the lever having a spring-engaging portion 5 engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat; and the side pivot, the spring-engaging portion, and the seat-biasing portion being spaced from each other and arranged so that the spring biases the lever about a 10 fulcrum located generally at the side pivot to bias the back toward the upright position, wherein the lever comprises an L-shaped bell crank and the fulcrum is located generally along an intermediate portion of one 15 leg of the L-shaped bell crank.

## 37. A chair comprising:

- a base assembly including a control housing having opposing side flanges and a side pivot located proximate one of the side flanges; 20
- a back pivoted to the base assembly for movement between upright and reclined positions;

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- a seat operably supported on the base assembly and connected to the back for coordinated synchronous movement with the back;
- an energy mechanism for biasing the back toward the upright position, the energy mechanism including an extendable/compressible spring positioned transversely and extending longitudinally side-to-side in the control housing with one end supported on one of the side flanges, and further including a lever pivoted to the side pivot, the lever having a spring-engaging portion engaging a free end of the spring and also having a seat-biasing portion operably connected to the seat; and 25 the side pivot, the spring-engaging portion, and the seat-biasing portion being spaced from each other and arranged so that the spring biases the lever about a fulcrum located generally at the side pivot to bias the back toward the upright position.

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